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MISCELLANEOUS PAPERS

ON

MECHANICAL SUBJECTS.

BY

JOSEPH WHITWORTH, F.R.S.

LONDON:
LONGMAN, BROWN, GREEN, LONGMANS, AND ROBERTS.
MANCHESTER: J. AND J. THOMSON.
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PREFACE.

THESE miscellaneous papers were written at various periods, some of them many years ago, and a few of the statements must be considered with reference to the objects for which they were respectively written, and to their dates. The paper upon plane metallic surfaces was read at the British Association in Glasgow, in the year 1840, with the view of showing how a true surface, or perfectly straight line, may be produced. At that time it was the custom to prepare what were intended to be used as original surfaces (presumed to be true) by grinding them ; and I was anxious to direct the attention of those engaged in mechanical pursuits to the inherent defects of the grinding process, and to prove the necessity of adopting the system of correction, by which alone error is eliminated, and surfaces practically true can be produced.

At the same time I urged the necessity of supporting all original surfaces or "true surface plates" on three points, that being the only means by which truth of surface can be maintained.

For some years prior to the date of the paper (in order to conciliate then existing prejudices) I used the grinding process to a limited extent, merely to give surfaces, such as those of slide-rests, the regular even appearance that was generally considered to be the proper indication of truth, to which I knew it in no way contributed.

Now, however, the mottled appearance produced by the scraping instrument is recognized as an indication of truth, and is sometimes applied to surfaces which have not undergone the process of correction, and are not true. It is very satisfactory to me to find that the advantages of the system are now universally recognized.

The paper on the screw threads was read at the Institution of Civil Engineers, in London, in the year 1841; since that time the system has been generally adopted in this country, and is becoming extensively used in America, and in other countries.

The report founded on the official visit of the Royal Commission (of which I was a member)

to the New York Exhibition, in 1853, was made in that year. It has been appended to the other papers, as many parts continue to be of interest, and inquiries are still made for it.

The address to the Institution of Mechanical Engineers was delivered in Glasgow in the year 1856, and the paper on "Standard Decimal Measures of Length" was read at the meeting of the Institution in Manchester in 1857, during which years I had the honour of being President.

The subject of rifled fire-arms, including artillery, has, during the last three years, occupied much of my time. It is so comprehensive in its nature that I have, in the following paper, purposely avoided going into details, and have confined myself to an explanation of the principles on which I have proceeded.

I could not help taking an interest in a subject so intimately connected with those branches of mechanics to which I have long paid special attention; believing as I do that the greater the precision with which fire-arms may be used at long distances, and the more their powers of destruction are increased, the more reluctant will civilized nations become to use them against each other, while, at the same time, a greater superiority will be given to wealth and civilization over mere numerical strength.

With these explanations I have thought it advisable to allow the earlier papers to remain in the form in which they were originally read, as in many respects the information they respectively contain, and the opinions then expressed, are applicable to the present time.

A PAPER

ON

PLANE METALLIC SURFACES

OR

TRUE PLANES,

READ AT THE

MEETING OF THE BRITISH ASSOCIATION IN GLASGOW, 1840.

ON

PLANE METALLIC SURFACES,

OR

TRUE PLANES.

THE method hitherto adopted * in getting up plane surfaces has been (after filing to the straight edge) to grind them together, with emery. In some cases it has been customary to try them previously on a surface plate, and to go over them with the scraping instrument; but they have always been ground afterwards. The surface plate itself has been invariably treated in the same manner.† The process of grinding is,

* That is, prior to the year 1840.

† Surface plates consist (as is well known to those familiar with our workshops) of iron plates, strengthened by ribs on their backs, and having their faces as smooth and as true as possible. They are used for the purpose of testing and correcting any surfaces which are required to be made true. A straight edge is also used for testing the truth of surfaces; it is generally so called when its surface is very narrow as compared with its length, being usually the side face of a long flat bar. Surface plates are made of various sizes.

A simple and interesting experiment may be tried with a

in fact, regarded as indispensable wherever truth is required, yet that of scraping is calculated to produce a higher degree of truth than has ever been attained by grinding. In reference to both processes a great degree of misconception prevails, the effect of which is materially to retard the progress of improvement, and which it is of great importance to remove. While grinding is universally regarded as indispensable to a finished surface, it is, in fact, positively detri-

pair of true surface plates. If one of them be allowed to slide on the other so as to exclude the air, the two plates are caused to adhere together with considerable force, by the pressure of the atmosphere. The surfaces should be well rubbed previously, with a dry cloth, till they are perfectly free from moisture, that the experiment may afford a fair test of accuracy. If any moisture be present it will act like glue, and cause adhesion to take place, supposing the surfaces to be much inferior. But if they be perfectly dry, adhesion proves a high degree of truth, rarely attained.

The experiment may be varied, by letting one surface descend slowly on the other, and thus allowing a stratum of air to form between them. Before they come into contact, the upper plate will become buoyant, and will float on the air without support from the hand. This remarkable effect would seem to depend on the close approximation of the two surfaces at all points, without contact in any—a condition which could not be obtained without extreme accuracy in both. The escape of the remaining portion of air is retarded by friction against the surfaces, the force of which nearly balances the pressure of the upper plate. If one end of the upper plate be slightly raised, and allowed to fall suddenly, the intervening air will act like a ushion, causing a muffled sound to be emitted, quite different from that usually produced by the concussion of metallic bodies.

mental. On the other hand, the operation of scraping, hitherto so much neglected, constitutes the only certain means we possess for the attainment of accuracy. A few remarks will clearly illustrate the truth of this statement.

It is required, in a plane surface for mechanical purposes, that all the bearing points should be in the same plane,—that they should be at equal distances from one another,—and that they should be sufficiently numerous for the particular application intended. Where surfaces remain fixed together, the bearing points may, without disadvantages be fewer in number, and, consequently, wider apart; but, in the case of sliding surfaces, the points should be numerous and close together.

A little consideration will make it evident that these conditions cannot be obtained by the process of grinding. And, first, with regard to general outline, how is the original error to be got rid of? Let it be supposed that one of the surfaces is concave, and the other a true plane. The tendency of grinding, no doubt, will be to reduce the error of the former, but the opposite error will, at the same time, be created in the true surface. The only case in which an original error could be extirpated, would be, when it was met by a corresponding error, of exactly the same amount, in the opposed sur-

face, and the one destroyed the other. But it is evident, that where only two surfaces are concerned, the variety of error in the general outline is not sufficient to afford any probability of mutual compensation.

It will further appear, that if the original error be inconsiderable, the surfaces must lose instead of gaining truth. It results from the nature of the process that certain parts are acted upon for a longer time than others. They are consequently more worn, and the surfaces are made hollow. Nor is there any possibility of obviating this source of error, except by sliding one surface entirely on and off the other, at each move, a method which, it need not be shown, would be impracticable.

It may be mentioned, as an additional cause of error, that the grinding powder collects in greater quantity about the edges of the metal than upon the interior parts, producing the well-known effect of the bell-mouthed form. This is particularly objectionable in the case of slides from the access afforded to particles of dirt, and the immediate injury thereby occasioned.

Another circumstance materially affecting the durability of ground slides is, that a portion of the emery employed becomes fixed in the pores of the metal, and causes a rapid and irregular wear of the surfaces.

If grinding be not adapted to form a true general outline, neither is it to produce accuracy in the minuter detail. There can be little chance of a multitude of points being brought to bear, and distributed equally, under a process from which all particular management is excluded. To obtain any such result, it is necessary to possess the means of operating independently on each point, as occasion may require, whereas grinding affects all simultaneously. It is subject neither to observation nor control. There is no opportunity of regulating the distribution of the powder, or of modifying its application, with reference to the particular condition of different parts of the surface. The variation in the quantity of the powder and the quality of the metal, will, of necessity, produce inequalities, even supposing they did not previously exist. Hence, if a ground surface be examined, the bearing points will be found lying together in irregular masses, with extensive cavities intervening. An appearance, indeed, of beautiful regularity is produced, and hence, no doubt, the universal prejudice so long established in favour of the process. But this appearance, so far from being any evidence of truth, serves only to conceal error. Under this disguise surfaces pass without examination, which, if unground, would be at once rejected.

Another evil of grinding is, that it takes from the mechanic all sense of responsibility, and all spirit of emulation, while it deludes him with the idea that the surface will be ultimately ground true. The natural consequence is, that he slurs it over, trusting to the effect of grinding, and well knowing that it will efface all evidence either of care or neglect on his part.

It thus appears that the practice of grinding has altogether impeded the progress of improvement. A true surface, instead of being in common use, is almost unknown.* Few mechanics have any distinct knowledge of the method to be pursued for obtaining it, nor do practical men sufficiently advert, either to the immense importance, or to the comparative facility of the acquisition.

Due latitude must be allowed to the expression "true surface." Absolute truth is confessedly unattainable. Moreover, it would be possible to aim at a degree of perfection beyond the necessity of the particular case, the difficulty of attaining which would more than counterbalance its advantage. But it is certain that the progress hitherto made falls far short of this practical limit, and that considerations of economy alone would carry improvement many

* This, it must be borne in mind, had reference to the state of things existing in 1840.

degrees higher. The want of it in various departments of the arts and manufactures is already sensible. The valves of steam engines, for example;—the tables of printing presses,—stereotype plates,—surface plates,—slides of all kinds, require a degree of truth much superior to that they generally possess. In these, and a multitude of other instances, the want of truth is attended with serious evils. In the case of the slide valves of steam engines, there is occasioned a great loss of steam power, and also an immense increase of wear and tear.* In stereotype printing, inaccuracy of the plates renders packing necessary to obtain a uniform impression. A vast amount of time and labour is thus sacrificed, and the end is, after all, but imperfectly attained.

The extensive class of machinery, denomi-

* Mr. Dewrance, superintendent of the locomotive department of the Liverpool and Manchester Railway, in a letter to Mr. Whitworth, dated the 23rd of December, 1840, says,—"In answer to yours of the 20th inst. respecting the difference of the slide valves got up with emery, and those that are scraped or got up according to your plan, the difference is as follows:—I have this day taken out a pair of valves got up with emery that have been in constant wear five months, and I find them grooved in the usual way. The deepest grooves are one-eighth of an inch deep, and the whole surface, which is eight inches broad, is one-sixteenth hollow, or out of truth. Those that were scraped are perfectly true, and likely to work five months longer."

nated engine tools, affords an important application of the subject. Here every consideration combines to afford accuracy. It is implied in the very name of the planing engine. The express purpose of that machine is to produce true surfaces, and it is itself constructed of slides, according to the truth of which will be that of the work performed. When it is considered that the lathe and the planing engine are used in the making of all other machines, and are continually re-producing surfaces similar to their own, it will manifestly appear of the first importance, that they should themselves be perfect models.* There is, perhaps, no description of machinery which would not afford an illustration of the importance belonging to truth of surface, and at the same time, of the present necessity for material improvement; nor is there any subject connected with machines, the bearings of which, on public interests, whether manufacturing or scientific, are more varied or more extensive.

The improvement so much to be desired, will speedily follow upon the discontinuance of grinding. Recourse must then be had to the natural process. The surface plate and the

* It is plain that, in machines intended to be used in reproducing other machines, errors in surface are of the utmost consequence, for the original defects are propagated in an aggravated form.

scraping instrument will come into constant use, affording the certain and speedy means of attaining any degree of truth which may be required. A higher standard of excellence will be gradually established, the influence of which will be felt throughout all mechanical operations, while, to the mechanic himself, a new field will be open, in which he will find ample scope for the exercise of skill, both manual and mental.* The subject will be best illustrated by a description of the process.

There are two cases for consideration, in reference to the preparation of surfaces,—the one, where a true surface plate is already provided, as a model for the work in hand, and the other, where an original surface is to be prepared.

The former case is that which will generally occur in practice. The method to be pursued is simple, and requires care rather than skill. Colouring matter, such as red ochre and oil, is spread over the surface plate, *as equally as possible;* the work in hand, having been previously filed up to the straight edge, is then applied thereto, and moved slightly to fix the colour, which, adhering to the parts in contact, afterwards shows the prominences to be removed

* It is satisfactory to be able to state that the results here anticipated have been long ago realized

by the scraping instrument, and the operation is frequently repeated. As the work advances, a smaller quantity of colouring matter is used, till at last, a few particles spread out by the finger suffice for the purpose, forming a thin film over the brightness of the plate. A true surface is thus rendered a test of the greatest nicety, whereby the smallest error may be detected. At this stage of the process, the two surfaces must be well rubbed together, that a full impression may be made by the colour. The higher points on the rising surface become clouded over, while the other parts are left more or less in shade. The dappled appearance thus produced, shows to the eye of the mechanic, the precise condition of the new surface in every part, and enables him to proceed with confidence in bringing it to correspondence with the original. Before this can be accomplished, however, the scraping instrument must be employed, the file not having the precision or nicety requisite to finish the operation. Experience will be a sufficient guide when to exchange the one for the other. It will be found, that when the parts to be operated upon have become to any considerable extent subdivided, scraping is much the more expeditious method. The instruments should be made of the best steel, and carefully sharpened to a fine edge on a

Turkey-stone, the use of which must be frequently repeated. They may be conveniently made of worn-out files. It will be matter of discretion, as before remarked, how far to proceed in working up the minute detail, but it is essential that the bearing points, whether more or less numerous, should be *equally distributed*, and a uniform character preserved throughout. This rule should be carefully observed during the progress of the work, as well as at its conclusion.

In order to secure the equal advance of all the parts together, particular attention must be paid to the colouring matter, both with reference to the quantity employed, and its equal distribution. If too small a quantity be used in the first instance, it will afford no evidence of the general condition of the surface. It will merely indicate the particular points which happen to be most prominent, and to reduce these in detail would be only a waste of time, so long as they are considerably above the general level.

When the surface is finished, if it be rubbed on the plate without colour, the bearing points will become bright, and the observer will be able to judge of the degree of accuracy to which it has been brought. If it be as nearly true as it can be made by the hand, bright points will be seen diffused throughout its whole extent, inter-

spersed with others less luminous, indicating thereby the degree of force with which they respectively bear.

In getting up a surface of considerable extent, it is necessary to take into account the strain which the metal suffers from its own weight, and the length of time required to produce the full effect on the external form. It will be found, for example, that after a piece of metal has remained for some days in one position undisturbed, it assumes a form different from that which it had while undergoing preparation. Hence, it is desirable to provide for the work while in hand, similar support to what it will have when applied to its intended use.

Another disturbing cause is the unequal contraction of the metal in cooling, when originally cast. The mass assumes the curved form, and is pervaded by elastic forces counteracting each other. These continue in permanent activity, and any portion of metal, taken from any part, tends to disturb the balance previously established.

It remains to consider the second case proposed, viz., how to prepare an original surface. A brief description of the proper method will still further illustrate the case already considered, and will also show how surface plates are to be corrected.

Take three plates of cast iron, of equal size and proportionate strength. The metal should be of a hard quality. The plates should be well ribbed on the back to prevent them from springing, and each of them should have three projecting points on which to rest, placed triangularly in the most favourable positions for bearing. The object of this provision is to insure constant support at the same points. The plate would otherwise be subject to perpetual variation of form, owing to the irregular strain, occasioned by change of bearing.* A provision of this kind is equally necessary while the plate is undergoing the operation of correction, and when it is afterwards used as a model.

In fixing the plates on the table of the planing machine, care should be taken to let them bear on the points before mentioned, and to chuck them with as little violence as possible to the natural form, otherwise they will spring on being released, and the labour of filing will be increased in proportion. It is proper also to relax the chucks before taking the last cut. With these precautions, if the machine itself be accurate, and the tool in proper condition, the

* The importance of always providing a proper support for standard surfaces is still very often overlooked. The tripod system is, as I have before stated, absolutely essential.

operation of planing will greatly facilitate the subsequent process. *

The plates are next to be tried by the straight edge, by a skilful use of which a very small degree of inaccuracy may be detected.

Let one of the three plates be now selected as the model, and the others be surfaced to it with the aid of colouring matter. For distinctness they may be called Nos. 1, 2, and 3. When Nos. 2 and 3 have been brought up to No. 1, compare them together. It is evident that if No. 1 be in any degree out of truth, Nos. 2 and 3 will be alike, and the nature of their error will become sensible on comparing them together by the intervention of colour. To bring them to a true plane, equal quantities must be taken in both from corresponding places. When this has been done with all the skill the mechanic may possess, and Nos. 2 and 3 are found to agree, the next step is to get up No. 1 to both, applying it to them in immediate succession, so as to compare the impressions. The art here lies in getting No. 1 between the two, which is the probable direction of the true plane. It is to be presumed that No. 1 is now nearer truth than

* The plates, after having been planed, should be allowed to rest for two or three weeks on their three bearing points. This will afford them time to settle in the form which they will naturally assume.

either of the others, and it is therefore to be again taken as the model, and the operation repeated.

It will be observed that the process now described includes three parts, and consists in getting up the surfaces to one another in the following order :—

1st. Nos. 2 and 3 to No. 1.

2nd. Nos. 2 and 3 to each other.

3rd. No. 1 to Nos. 2 and 3.

These parts compose an entire series, by repeating which a gradual approach is made to absolute truth, till further progress is prevented by inherent imperfection.

In the earlier stages, the operation may be greatly expedited by judicious management. It has been already remarked, but it cannot be too often repeated, that the general outline of the surface should be solely regarded in the first instance, and the filling up deferred till after general truth has been secured. By this method, the first course of the series will be short, and the progress made will be both more speedy and more sure, the minuter detail being gradually entered upon, without the risk, otherwise, incurred, of losing previous labour. As, however, the surfaces approach perfection, the utmost caution and vigilance will be necessary to prevent them from degenerating. This will inevitably

happen, unless the comparison be constantly made between them all.

In the use of the surface plate, care should be taken to prevent unnecessary injury, whether superficial or from straining. It should also be occasionally submitted to careful correction, and should invariably be supported on three points. In no other way can a high standard be maintained.

It will be found convenient to set apart one plate for the purpose of comparing others, allowing it to remain entirely undisturbed. It would otherwise be necessary, at every revision, to repeat the process for obtaining an original surface, and a considerable loss of time would thus be occasioned.

A mistaken idea prevails that scraping is a dilatory process,* and this prejudice may tend to discourage its introduction. It will be found, however, to involve the sacrifice of less time than is now wasted on grinding. Were the fact otherwise, it would be no argument against the preference due to the former. But it is worthy of observation that, in this instance, as in many

* When grinding was first discontinued in the establishment of Messrs. Whitworth and Co., no mechanic could be induced to take the work on the same terms as before, owing to the supposed extra labour of scraping. But experience has entirely removed this prejudice, and the work is now done with greater despatch.

others, improvement is combined with economy. There is not only an incalculable saving effected by the improved surface, in its various applications, but there is also a positive gain of time in the preparatory process.

A PAPER

ON AN

UNIFORM SYSTEM OF SCREW THREADS,

READ AT THE

INSTITUTION OF CIVIL ENGINEERS, IN 1841.

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A PAPER

ON AN

UNIFORM SYSTEM OF SCREW THREADS.

[READ AT THE INSTITUTION OF CIVIL ENGINEERS IN 1841.]

THE screw threads which form the subject of this paper are those of bolts and screws, used in fitting up steam engines and other machinery. Great inconvenience is found to arise from the variety of threads adopted by different manufacturers. The general provision for repairs is rendered at once expensive and imperfect. The difficulty of ascertaining the exact pitch of a particular thread, especially when it is not a multiple or submultiple of the common inch measure, occasions extreme embarrassment. This evil would be completely obviated by uniformity of system, the thread becoming constant for a given diameter. The same principle would supersede the costly variety of screwing apparatus, required in many establishments, and remove the confusion and delay occasioned thereby. It would also prevent the waste of bolts and nuts which is now unavoidable. The impulse and direction given to machinery during

late years have tended to increase these evils, and must, ultimately, lead to a change of system.* Take, for example, the refitting shop of a railway or steam packet company. Here the variety of apparatus rendered necessary by the want of uniformity will correspond with the number of different manufacturers by whom the engines are supplied, whereas, if the same system of screw threads were common to the different engines, a single set of screwing tackle would suffice. The economy and manifold advantages resulting from uniformity in this instance, would be sufficiently obvious.

Supposing the same principle extended throughout engineering and other establishments until its application became general, the advantage would be proportionally greater, and would assume a character of public importance. Public convenience would be promoted in various ways easy to trace, though leading to results perhaps little to be expected, and the economy of screwing apparatus, however considerable, would become insignificant when compared with the contingent benefit to other interests.

Were an uniform system adopted for marine or locomotive engines there can be no doubt that it would be extended to engines and machi-

* Since 1841, when this was written, the system of screws here recommended has been universally adopted.

nery of almost every description. Peculiar threads will, of course, be always required for particular purposes, but in screws for general use in fitting up machinery, the advantage of uniformity would be paramount to every other consideration.

It does not appear that any combined effort has been hitherto made to attain this object. As yet there is no recognized standard. This will not be matter of surprise, when it is considered that any standard must be, to a great extent, arbitrary. It is impossible to deduce a *precise* rule for the threads of screws from mechanical principles, or from any number of experiments. On the other hand, the nature of the case is such that mere approximation would be unimportant, absolute identity of thread for a given diameter being indispensable.

To how great an extent the choice of thread is arbitrary will appear from a cursory consideration of the principles affecting it. Without attempting to discuss these in detail, which would be foreign to the present purpose, it may be interesting to notice the general outline and bearings of the subject.

The use of the screw bolt is to unite certain parts of machinery in close and firm contact. It is peculiarly adapted for this purpose by the compact form in which it possesses the necessary

strength and mechanical power. The extreme familiarity of the object tends to prevent the observation of its peculiar fitness. Yet, among all the applications of mechanics, there is, perhaps, no instance of adaptation more remarkable. The ease with which distinct parts of machinery can be united, the firmness with which they are held together, and the facility with which they may be separated, are conditions of the utmost importance, which by no other contrivance could be combined in an equal degree.

While, however, the utility of the screw in this application is abundantly obvious, it is by no means evident what may be the precise formation most advantageous under all circumstances. No exact data of any kind can be obtained for calculation, and the problem will be found to be capable only of approximate solution.

The principal conditions required in the screw bolt are power, strength, and durability—the latter having reference to the wear occasioned by frequent fixing and unfixing. But none of these conditions can be reduced to a definite quantity. We cannot, for example, determine the exact amount of power necessary to draw the parts of a machine into due contact, or the precise degree of strength which may suffice for resisting the strains to which they

may be afterwards exposed. Hence, we cannot lay down any rule for choosing the diameter of the screw bolt required for a given purpose. Practical men can judge of the proper size with considerable nicety, but they have no means of ascertaining it with absolute precision.

If the diameter be given, and it be required to find the proper thread, the nature of the question is not essentially altered. The amount neither of power, nor of strength (nor any other condition), is thereby determined. A certain limit is assigned, but within that limit the proportions of strength and power, &c., may vary indefinitely, according to the actual formation of the thread.

There are three essential characters belonging to the screw thread, viz., pitch, depth, and form. Each of these may be indefinitely modified independently of the others, and any change will more or less affect the several conditions of power, strength, and durability.—The mechanical power of the screw depends on the pitch, which for a given diameter determines the angle of the inclined plane, and on the form of thread which regulates the direction in which the force applied will act.—The strength of the screw in the thread varies with each of the three characters; in the centre part, being as the area, it is little affected, except by change of depth.—The durability of

the thread also depends chiefly on its depth, and the proper depth is determined principally with reference to this condition. In the selection of the thread considerable latitude of choice will be found to prevail with reference to all the characters. No definite rule can be given for determining any one of them. It may be manifest that particular threads are too coarse or too fine, too deep or too shallow; but there are intermediate degrees within which the choice of thread like that of the diameter is arbitrary, and must be guided rather by discretion than by calculation.

The mutual dependence of the several conditions required in the thread may be noticed as having a tendency to perplex the choice. Thus increase of power is necessarily attended with diminution of strength. The square thread which has the advantage in respect of power is proportionally weaker than the angular thread. A fine thread loses in strength, while it gains mechanically as compared with a coarser. Deep threads also, while they are more durable than shallow, materially detract from the strength of the bolt.

The selection of the thread is also affected by the mutual relation subsisting between the three constituent characters of pitch, depth, and form. Each of these, as before observed, may be sepa-

rately modified; but practically no one character can be determined irrespective of the others. The pitch of the square thread is generally twice that of the angular for the same diameter, to retain similar proportions of power and strength. Coarse threads should be deep as compared with fine, to provide against the wear from friction. A coarse angular thread will also require additional depth to preserve the due proportion of power, and to prevent the longitudinal strain from being thrown too much sideways on the nut. Hence, each character acts as a limit to the variation of the others, and in some instances (that is, in the case of certain diameters), it will be found that the leading consideration in fixing one character is the resulting effect on another. Thus, in some of the smaller sizes, the pitch is determined principally by reference to the depth—a coarser thread being objectionable, because the extra depth would too much weaken the centre part of the bolt—while the necessary shallowness of a finer thread would render it too liable to wear with friction.

The proportional strength of the thread and centre part of the screw is regulated mainly by the depth of the nut, which is generally of the same measure as the diameter of the bolt. Assuming that dimension as fixed, the proportion of strength between the two parts will vary with

the different characters of thread, and more particularly with the depth. The centre part not being liable to wear while the thread is subject to friction and accidental injury, the original proportion of strength ought to be considerably in favour of the thread.

Such being the variety and vagueness of the principles avowed in the subject, a corresponding latitude might naturally be expected in their practical application, and accordingly we find, instead of that uniformity which is so desirable, a diversity so great as almost to discourage any hope of its removal. The only mode in which this could be attempted with any probability of success would be by a sort of compromise, all parties consenting to adopt a medium for the sake of common advantage. The average pitch and depth of the various threads used by the leading engineers would thus become the common standard, which would not only have the advantage of conciliating general concurrence, but would, in all probability, be nearer the true standard for practical purposes than any other.

Messrs. Whitworth and Company were led, some years ago, to alter the threads of their screws on this principle, in consequence of various objections urged against those they had previously adopted, and the result of the experiment has been abundantly satisfactory.

An extensive collection was made of screw bolts from the principal workshops throughout England, and the average thread was carefully observed for different diameters. The $\frac{1}{4}$, $\frac{1}{2}$, 1, and $1\frac{1}{2}$ inches were particularly selected and taken as the fixed points of a scale by which the intermediate sizes were regulated. The only deviation made from the average was such as might be necessary to avoid the great inconvenience of small fractional parts in the number of threads to the inch. The scale was afterwards extended to 6 inches.

The pitches thus obtained for angular threads are shown in the following table:—

Diameter in Inches ..	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$
Threads to the Inch ..	20	18	16	14	12	11	10	9	8	7	7
Diameter in Inches ..	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$
Threads to the Inch ..	6	6	5	5	$4\frac{1}{2}$	$4\frac{1}{2}$	4	4	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{4}$
Diameter in Inches ..	$3\frac{1}{2}$	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{3}{4}$	5	$5\frac{1}{4}$	$5\frac{1}{2}$	$5\frac{3}{4}$	6
Threads to the Inch ..	$3\frac{1}{4}$	3	3	$2\frac{7}{8}$	$2\frac{7}{8}$	$2\frac{1}{4}$	$2\frac{3}{4}$	$2\frac{5}{8}$	$2\frac{5}{8}$	$2\frac{1}{2}$	$2\frac{1}{2}$

It will be observed that above 1-inch diameter the same pitch is used for two sizes. This could not have been avoided without introducing small fractional parts. The economy of screwing apparatus was also promoted by repetition of the thread.

It is important to remark that the proportion

between the pitch and the diameter varies throughout the entire scale. Thus the pitch of the $\frac{1}{4}$ inch is one-fifth of the diameter—that of the $\frac{1}{2}$-inch, one-sixth—of the 1-inch, one-eighth —of the 4-inch, one-twelfth—of the 6-inch, one-fifteenth. It is obvious that more power is required as the diameter increases. But this consideration alone will not account for the actual deviation, which is much less than it would be if the scale were calculated with reference to the power required. The amount of power necessary must be determined in relation to the muscular force of the human arm, aided by the leverage of the screw key. Now, in the case of smaller screws, there is a considerable excess of force. Again, in the larger, there will be found a deficiency of power, for with all the leverage which can generally be applied, it requires the force of several men to fix a bolt of six inches diameter. Hence it is evident that at the two extremes of the scale the amount of power required is not the leading consideration in fixing the pitch of the thread. In the smaller sizes the necessary depth of a coarser thread—as before observed—would too much weaken the centre part of the screw. It may also be mentioned that coarse threads would render small screws apt to work loose for want of sufficient hold to prevent the effect of jarring.

On the other hand, finer threads on large bolts besides being weaker and less durable, would render it difficult to unfix them when occasion required.

It will be remembered that the threads, of which the preceding table shows the average, are used in cast iron as well as wrought; and this circumstance has had its effect in rendering them coarser than they would have been, if restricted to wrought iron.

The variation in depth among the different specimens was found to be greater proportionally than in pitch. The angle made by the sides of the thread will afford a convenient expression for the depth. The mean of the variations of this angle in 1-inch screws was found to be about 55°, and this was also pretty nearly the mean of the angle in screws of different diameters. As it is for various reasons desirable that the angle should be constant, more especially with reference to general uniformity of system, the angle of 55° has been adopted throughout the entire scale. A constant proportion is thus established between the depth and the pitch of the thread. In calculating the former, a deduction is to be made for the quantity rounded off, amounting to one-third of the whole depth—that is, one-sixth from the top, and one-sixth from the bottom of the thread. Making this

deduction it will be found that the angle of 55° gives for the actual depth rather more than three-fifths, and less than two-thirds of the pitch. The precaution of rounding off is adopted to prevent the injury which the thread of the screw, and that of the taps and dies, might sustain from accident.

The system of threads selected in the manner above described has already obtained greater extension than any other. It has been adopted exclusively on many of the railways, and in some of the most extensive engineering establishments in England and Scotland. During the present year it has been introduced into the Royal Dock-yard at Woolwich, and it is now being applied to the engines constructing for the Royal Mail Steam Packet Company. There is therefore reason to hope this system may be instrumental in promoting the proposed object of uniformity, of which it already exemplifies the practicability and advantage.

But the difficulty of obtaining a concurrence of opinion in favour of a particular system is not the only one to be encountered. The inconvenience to existing establishments which any change would involve is calculated to retard the prevalence of an approved system, nor could general co-operation be reasonably expected unless there were a certain prospect of success.

This, however, is an obvious reason why the attention of engineers should, without loss of time, be directed to the subject.

It will probably occur to practical men that there are other obstacles to be surmounted before the principle of uniformity can be carried into full operation. The great want of accuracy in screwing and tapping by the ordinary process may be particularly mentioned. To whatever extent this may prove an obstruction, it may be also regarded as an additional motive for urging the subject on general attention. The necessity for greater correctness will thus be placed in a new and stronger light, and the effect no doubt will be a material improvement in this essential respect. It is mainly for want of accuracy that screw bolts so frequently fail. Unless the threads of the screw and nut exactly correspond in every part, and coalesce throughout their whole length and depth, their mutual action is completely deranged, power and strength are both sacrificed, and friction is proportionally increased. The immense consumption of bolts and nuts in fitting up and working machinery may give some idea of the extent to which greater accuracy might be productive of economy.

To maintain uniformity, provision must be made for multiplying standards of the diameters and threads. This may be easily done, and will

prevent the screwing tackle from degenerating by use and propagation.

This part of the case is connected with a subject of great extent which, under every aspect, lays claim to the attention of practical engineers. We allude to the general use of standard gauges, graduated to a fixed scale, as constant measures of size. It is quite practicable by such means to work to a common measure with a degree of accuracy sufficient for all ordinary purposes. Corresponding parts, instead of being got up one to another, might be prepared separately. The indefinite multiplication of sizes would thus be prevented, and the economy of the workshop simplified to an extent beyond calculation.

ADDRESS

DELIVERED TO THE

INSTITUTION OF MECHANICAL ENGINEERS

GLASGOW, 1856.

ADDRESS TO THE INSTITUTION OF MECHANICAL ENGINEERS.

DELIVERED AT GLASGOW, 1856.

GENTLEMEN,—This being the first time I have taken the chair since you did me the honour to elect me your President for the present year, I propose to address you shortly on a few topics more or less connected with our profession of mechanical engineering. But first, let me express my gratification, and I am sure that of my fellow-countrymen, in thus meeting our northern friends in this important city.

Glasgow is peculiarly interested in the mechanical arts, for the minerals for making iron are found in great abundance in this locality; indeed, it is to this neighbourhood, more than to any other, that the world is indebted for the cheapest and most abundant supply of iron. Here, too, that metal is converted into a great variety of machinery. There are large manufactories of the steam-engine — fixed,

marine, and locomotive. Cotton, manufacturing, and various other kinds of machinery are also made here in considerable quantities. With such links of connection amongst us, I trust that this, our first meeting in this city, may be the forerunner of many others, and that we shall add many members to our Institution.

Great attention is now being paid to improvements in the manufacture of malleable iron and steel. I need not tell you of what vast importance it must be to those who are more immediately connected with those branches of mechanics requiring nicety of workmanship, to have iron and steel of a better quality. I may mention that in making rifle-barrels for the experiments which I have undertaken for the Government, one of the greatest difficulties I encounter, in attaining the degree of accuracy that I require, arises from the defects in the metal. What we want is iron of great strength, free from seams, flaws, and hard places. Inferior iron (with the use of other defective and improper materials) is perhaps the main cause of one of the greatest errors committed in the construction of whatever in mechanism has to be kept in motion. I mean the increase of size of the parts of a machine or carriage, in order to get strength, thereby adding weight until they are considered to be strong enough. In our vehicles of draught

and carriages this is strikingly the case. Now this ought not to be. Lightness is the thing to aim at, and safety should be sought in the elasticity, form, and good quality of the material. Should a carriage be found to twist and get out of form, that would be a proof of its being too light. But to prevent a carriage breaking down by increasing the size of its parts, and thereby adding weight, instead of improving quality, is mechanically wrong. Indeed, it is quite distressing to see the enormous weight of our carriages, particularly those drawn by animal power. It should be an axiom in mechanics that whatever has motion should be as light as circumstances will admit; this applies equally, whatever the source of power may be, whether the motion is produced by human, horse, or steam power.

I would next call your special attention to the vast importance of attending to the two great elements in constructive mechanics — namely, *a true plane* and *the power of measurement*. The latter cannot be attained without the former, which is therefore of primary importance; and its accomplishment is so easy and so simple as to leave without excuse any establishment neglecting to secure it. It is necessary to make three planes in order to obtain a perfect one, and cast iron is the best material generally to use. Whatever the size of the plane required, the tripod form is

absolutely essential for its support; and the strengthening ribs must be placed with reference to the supports. I cannot impress too strongly on the members of the Institution, and upon all in any way connected with mechanism, the vast importance of possessing a true plane, as a standard for reference. All excellence in workmanship depends upon it. I may mention that it was at the meeting of the British Association held in Glasgow in 1840 that I read a paper on the mode of producing a true plane, to which I would refer those desiring information on the subject.*

Next in importance to a true plane is the power of measurement. I have brought with me, for your inspection at the close of the meeting, a small machine, by which a difference in length of the one-millionth part of an inch is at once detected. The principle is that of employing the sense of touch, instead of sight. If any object be placed between two parallel true planes, adjusted so that the hand can just feel them in contact, you will find, on moving the planes only the 50-thousandth of an inch nearer together, that the object is distinctly tighter, requiring greater force to move it between them. In the machine before you, the object to be measured is the standard inch, in the form of a small

* See ante pages 3—19.

square bar, both ends being true planes; and in this case, in order to measure with the utmost accuracy, a thin flat piece or bar is introduced, having its two sides made also perfect planes. This is placed between the inch bar to be measured and one of the end surfaces of the machine. This thin bar, which I name the gravity piece, is brought into contact with the two planes, so as just to allow it, on being raised, to fall by its gravity; and you will find that, by bringing the planes into closer contact by even the one-millionth of an inch, the gravity piece will be suspended, friction overcoming its gravity. This machine and a larger one, are used for making standards of length. When the standard yard, which is a square bar of steel, is placed in the larger machine, and the gravity piece adjusted so as just to fall by its weight, the heat imparted from the slightest touch of the finger instantly prevents its fall, thus showing the lengthening of the bar by so small an amount of heat as that I have indicated. We have therefore in this mode of measurement all the accuracy we can desire; and we find in practice in the workshop that it is easier to work to the ten-thousandth of an inch from standards of end measure, than to the one-hundredth of an inch from the lines on a two-foot rule. In all cases of fitting, end measures of length should be used, instead of lines.

The question of correct measurement is in immediate connexion with another, which will repay all the attention that can be given to it, and I think there is no subject that can be more profitably discussed amongst us;—I mean that of *proper gradations of size* in all the various branches of the mechanical arts. I think no estimate can be formed of our national loss from the over-multiplication of sizes. Take for instance the various sizes of steam-engines—stationary, marine, and locomotive. In the case of marine engines, the number of sizes up to 100 horse-power will probably not be short of thirty, where ten perhaps would be ample. If so, look at the sums expended in patterns, designs, and in the number of tools for their manufacture. Nor is this all; for if there were only ten sizes instead of thirty, there would be three times the number made of each pattern; and, as you know, the very soul of manufacture is repetition. By attention to this, the shipowner would be benefited by getting a better engine at a less price. In the case of locomotives and carriages, I would urge the subject on the attention of our members, the engineers of the great lines of railway—the London and North-Western, the Midland, the Great Northern, for instance. I hope they will permit me to suggest that they should consider and determine

not only the fewest possible number of sizes of engines and carriages that will suffice, but also how every single piece may have strictly defined dimensions. This question is also well worthy the attention of our architects and builders. Suppose, for instance, that the principal windows and doors of our houses were made only of three or four different sizes. Then we should have a manufactory start up for making doors, without reference to any particular house or builder. They would be kept in stock, and made with the best machinery and contrivances for that particular branch; consequently, we should have better doors and windows at the least possible cost. Our friends across the Atlantic manage matters in connexion with their buildings much better than at present we do.

I hope the members of this Institution will join me in doing what we can with reference to those two important subjects—correct measurement, and its corollary, proper gradations of size. The want of more correct measurement seems to prevade everything. Take, for instance, the case of the common brick, which ought to be three inches thick. Who is there that has made an addition to a building who has not felt inconvenience from the irregularity of size?—the new brick being, perhaps, too thick, and so

not allowing sufficient mortar to be used; or too thin, and requiring too much mortar.

Perhaps one of the most effectual means that could be adopted, in the first instance, to remedy this unsatisfactory state of things, would be for the Government to supply corporate bodies with proper standards of length—such as the inch, the foot, and the yard. The corporate bodies themselves might then have their own standards of size, founded on these, and made to suit the particular wants of the different trades in the locality. The only standard of length at present supplied by the Government and kept by the corporate bodies is the standard yard; but there is so little attention paid to accuracy, that to the engineer and machinist it is not of the slightest use, and is only employed to adjust yard sticks for measuring woven goods.

There is also another subject which bears upon this question, and which has lately been before the Legislature—that of decimalising weights and measures. There can be no doubt of the beneficial results that would follow the passing of such a measure. There may be a difference of opinion as to what the unit or integer of lineal measure should be; but I think that it should be the inch, for, from the accuracy with which we can now measure that length, there would be no difficulty in determining and fixing

the length of its multiples. The most important divisions of length in mechanism are those of parts of an inch, and if the length of the inch were altered it would cause much confusion. Small accurate standards of length, of the decimal parts of an inch, would be of much service to some trades. There is now no standard of appeal; and the different wire and other gauges differ so considerably, that the manufacturer, in the case of small wire and sheets of metal, has to send a sample of what he wants, there being no means of correctly expressing its size.

Although I have said so much to you with reference to the desirableness of further improvement and greater perfection in the mechanical arts, I congratulate you on the success which in our time they have attained, and the high consideration in which they are held. Inventors are not now persecuted, as formerly, by those who fancy that their inventions and discoveries are prejudicial to the general interests, and calculated to deprive labour of its fair reward. Some of us are old enough to remember the hostility manifested to the working of the power-loom, the self-acting mule, the machinery for shearing woollen cloth, the thrashing machine, and many others. Now, the introduction of the reaping and mowing machine, and other improved agri-

cultural machinery, is not opposed. Indeed, it must be obvious to reflecting minds that the increased luxuries and comforts which all, more or less, enjoy are derived from the numerous recent mechanical appliances and the production of our manufactories. That of our cotton has increased during the last few years in a wonderful degree. In 1824, a gentleman with whom I am acquainted sold on one occasion one hundred thousand pieces of 74 reed printing cloth at 30*s*. 6*d*. per piece of 29 yards long; the same description of cloth he sold last week at 3*s*. 9*d*. One of the most striking instances I know of the vast superiority of machinery over simple instruments used by the hand is in the manufacture of lace, where one man with a machine does the work of 8,000 lacemakers on the cushion. In spinning fine numbers of yarn, a workman on a self-acting mule will do the work of 3,000 hand-spinners with the distaff and spindle; and there are other striking facts of a similar kind mentioned in my Report on the New York Industrial Exhibition.*

Comparatively few persons, perhaps, are aware of the increase of production during our lifetime. Thirty years ago, the cost of labour for making a surface of cast iron true, by chipping and filing by the hand, was 12*s*. per square foot; the same work is now done by the planing machine

* See post, page 87, et seq.

at a cost for labour of less than 1*d.* per square foot, and this, as you know, is one of the most important operations in mechanics. It is therefore well adapted to illustrate what our progress has been. At the same time that this increased production is taking place, the fixed capital of the country is, as a necessary consequence, augmented; for, in the case I have mentioned of chipping and filing by the hand, when the cost of labour was 12*s.* per foot, the capital required for tools for one workman was only a few shillings; but now the labour being lowered to 1*d.* per foot, a capital in planing machines for the workmen is required, which often amounts to £500, and in some cases more. This large outlay of capital, invested in machinery to increase production, makes it very difficult to curtail the hours of working machinery, as much as could be desired. In some cases two sets of workpeople have been employed in relays, each working eight hours a day; and this system perhaps may in time be extended, although it is attended with certain inconveniences. If, however, the relay system could be so improved and organised as to allow more time for the better education of young operatives, none would more cordially rejoice than myself. I believe that the science of mechanics, though a mere material power in itself, may, if rightly used, become a

moral lever, by which, like Archimedes of old, we may seek to raise the world.

There is at the present time a very gratifying circumstance in connection with the extension of machinery; namely, the large remuneration which operatives who work machines actually receive compared with those who perform hand labour without the help of machinery. I would here mention, with reference to the amount of wages paid to the operative, that it does not depend solely on the master manufacturers of this country, but is governed in some measure by what is paid by the manufacturers of other countries who are in competition with our own. When I was in America in 1853, I found that the American operatives received somewhat more wages than are paid in this country; but they worked much longer hours, although the climate, during some parts of the year, is so unfavourable. These longer hours enable the American manufacturer to turn over his capital more frequently.

This question of increased production, with which we, as mechanical engineers, are so identified, is so entirely dependent upon the power of the people to consume, that I hope I shall be excused in adverting to it. Our yearly exports now amount to about a hundred millions sterling, having doubled in a short time, while our home

productions have been greatly increased from the same cause, namely, the increased ability of our people to consume. As a general principle it would seem to be far better to levy a small impost on the entire wealth of an individual rather than to fasten a tax on particular objects, which if produced would constitute wealth, but which are not made because of the threatened impost. The remaining duty on carriages seems to me to be one of this description. Were there no tax, almost every one who keeps one carriage would keep more, while large numbers would have one who now have none. By their use locomotion would be increased threefold, and hence much valuable time would be saved. Besides, a large number of the best description of artisans would be called into existence for their manufacture—a class, too, who are well able to turn their hand, in cases of necessity, to other employment. If, therefore, it is desirable for a nation to possess wealth in carriages, it is a mistake for legislation to prevent it.

Formerly, when the wealth of a nation was produced, as it were, by hand labour, a different state of things existed to that of the present day. As I have shown, our means of production are now increased in some cases more than a hundred and in others more than a thousand fold; and this will go on, just in proportion as the masses of

our people are able to consume larger quantities of everything that they require. When the farm labourer pays less for his sugar and tea, more meat will be consumed (which again goes to improve the land); also more wool for our manufactures.

In this wonderful power of producing wealth which now exists, none can be more interested and benefited than the proprietors of the land. A striking proof of this is given by its increased value in the manufacturing counties, and for miles adjoining our manufacturing towns. The competition, too, of our manufacturers and merchants to become possessors of land is shown by the small rate of interest with which they are satisfied, for the outlay of their capital on the soil. The proprietors of land may rest assured that, in the future development of mechanical improvements, none will be more benefited than themselves. I do not hesitate to say that all harvest operations on land, properly laid down, will very shortly be performed in one-fourth the time required with the hand labour now expended, by the farther application of machines worked by horse-power. This is my conviction, based upon the experience I have had in the successful working of the machine I constructed for sweeping the streets, and at the same time filling the cart, by horse-power. By the combined aid of

mechanical improvements and the science of chemistry, together with the greater skill of our modern agriculturists, the culture of the land throughout Great Britain must more and more approximate to that of a garden.

We have seen the effect of the repeal of the duties on glass and bricks, in the improved appearance and reduced cost of residences, and a still further benefit may be expected to result from the removal of the remaining duty on timber. While, therefore, we congratulate ourselves on the great results which the mechanical arts have achieved, we have every reason to be thankful that our legislators have removed so many impediments to our progress. The glorious fruits of the legislative labours of that great and good man, Sir R. Peel, may give us hope that the time is not far distant when all remaining obstacles of this kind will be swept away. When that period has arrived, and when the industry of this country has been systematised upon sound principles of economical science, and in each department carried nearer to those standards which, in the case of mechanics, I have endeavoured to indicate, we shall have less reason than at present to doubt the stability of our manufacturing pre-eminence.

A PAPER

ON

STANDARD DECIMAL MEASURES OF LENGTH,

READ AT THE

MEETING OF THE INSTITUTION OF MECHANICAL ENGINEERS, MANCHESTER, 1857.

STANDARD DECIMAL MEASURES OF LENGTH.

MANCHESTER, 1857.

IN the address which I had the honour of delivering before the Members of this Institution at the Glasgow Meeting last year, I briefly alluded to the beneficial results which would follow the application of the decimal system to our weights and measures, referring more particularly to the latter. In compliance with the wish expressed by several members of the Council, I propose in the present paper to bring this important subject more prominently under the notice of the members, confining myself, however, to its practical bearing on mechanical operations, without discussing different systems of notation, which I leave to other and abler hands.

I have long been convinced that great and rapid progress would be made in many branches of the mechanical arts if the decimal system of

measures could be generally introduced. To state the case broadly, instead of our engineers and machinists thinking in eighths, sixteenths and thirty-seconds of an inch, it is desirable that they should think and speak in tenths, hundredths, and thousandths. I can assure those who have been accustomed to the fractional system that the change to the more perfect decimal one is easy of attainment, and, when once made, it will from its usefulness and convenience amply repay any trouble which may have attended its acquirement. In the manufacture of my standard gauges of size, the workmen measure to the 1-20,000th of an inch, and these measures are as familiar and appreciable as those of any larger dimensions. It will therefore be at once conceded that the only scale of measurement which can be used for such small sizes and proportionally small differences must be a decimal one, as any other would be productive of insurmountable difficulty, if not of utter confusion.

When the sizes of the fitting parts of machines are determined by sight from the lines on a scale or a two-foot rule, such nicety of measurement is out of the question; and as long as they are made on that system, the progress of improvement will be retarded. My experience has satisfied me that no system of measurement depending on the power of sight is suitable for

obtaining the size of the working parts of machines. Where exact size or good fitting is required, the sense of touch is far more to be depended upon. I make standards of size by a system of measurement depending for its accuracy upon the sense of touch; and use an instrument provided with a mechanical multiplier, by which a space is presented to the eye many thousand times greater in extent than is the case where the distance is directly measured by sight only.

With truth of surface, that never-failing element of success, as the basis of operation, we are enabled to measure with exactitude; and there is no difficulty in making parts of machines to fit one another with any degree of nicety: but, when we wish to express correctly by the common fractional system very minute measurements, our ideas are cramped and hampered by an inconvenient and often confused system of notation. What exact notion can any man have of such a size as "a bare sixteenth" or "a full thirty-second;" and what inconvenient results may ensue from the different notions of different workmen as to the value of these terms. A scale of notation that may have suited the old system of manufacture has been left behind, I am happy to say, as the present age has improved on the past; and our improvement has created a want

which necessity urges us to supply without delay. In the production of duplicate parts of machinery, correct measurement is indispensable to ensure good work: and if, as is the case, we are able to measure with all the accuracy and nicety that can be required, we surely ought at once to adopt a system of notation which will properly represent our measurements.

As an illustration of the importance of very small differences of size, I have brought an internal gauge having a cylindrical aperture ·5770 inch diameter, and two external gauges or solid cylinders, one being ·5769 inch, and the other ·5770 inch diameter. The latter is 1-10,000th of an inch larger than the former, and fits tightly in the internal gauge when both are clean and dry; while the smaller ·5769 inch gauge is so loose in it as to appear not to fit at all. These gauges are finished with great care, and are made true after being casehardened. They are so hard that nothing but the diamond will cut them, except the grinding process to which they have been subjected. The effect of applying a drop of fine oil to the surfaces of these gauges is very remarkable. It will be observed that the fit of the larger cylinder becomes more easy, while that of the smaller becomes more tight. These results show the necessity of proper lubrication. In the case of the external gauge ·5770

inch diameter, the external and internal gauges are so near in size that the one does not go through the other when dry, and if pressed in, there would be danger of the surface particles of the one becoming imbedded in or among those of the other, which I have seen happen, and then no amount of force will separate them: but with a small quantity of oil on their surfaces, they move easily and smoothly. In the case of the external gauge ·5769 inch diameter, which is 1-10,000th of an inch smaller in diameter than the internal gauge, a space of half that quantity is left between the surfaces; this becomes filled with the oil, and hence the tighter fitting which is experienced.

It is therefore obvious both to the eye and the touch, that the difference between these two cylinders of 1-10,000th of an inch is an appreciable and important quantity; and what is now required is a method which shall express systematically and without confusion a scale applicable to such minute differences and measurements: it should be based on a uniform principle which will accustom the workman to speak of his measures as aggregates of very small differences; and when a good workman becomes familiar with such sizes as 1-1000th and 1-10,000th of an inch, he will not rest satisfied until he can work with corresponding accuracy. He will also be

able to judge of their effect under different circumstances, and know how much to allow in the fitting parts of a machine, according to their relative importance and the treatment they are likely to receive at the hands of the attendant. For instance, the cylinder of the moving headstock of a lathe requires as good a fit as possible; but in practice it is found that the cylinder must be ·0005 inch or 1-2000th of an inch too small, because it frequently happens that machinery is not kept in a proper state of cleanliness, or from motives of false economy is lubricated with bad oil. These are two evils which are productive of great mischief. The abrasion caused by accumulated dust and grit produces increased wear and tear, and soon injures the surfaces in contact; while bad oil becomes sticky and rancid, and spoils the working of a good fit.

And here let me state what I think is the proper definition of a good fit. A tight fit is not necessarily a good one; but when the surfaces are true, and a proper allowance is made in the size of the parts working together, then a good fit is obtained. What constitutes a proper allowance or difference in size depends on the nature of the case, and the treatment which the machinery will meet with. In machinery supplied to establishments using rape oil

there must be greater allowance and looseness in the fits than would be requisite if better oil, as sperm oil, were used. I need scarcely say how much more advisable it is to have the more accurate fit and use the best oil, than to have a loose fit and use the inferior oil, which causing more friction consumes greater power.

Again, a good workman acquires by experience an intuitive knowledge of the allowances in size which are requisite in various cases; and if a suitable decimal system of notation be adopted, there will be no difficulty, with the power of measurement we now possess, in registering minute differences; and so the knowledge gained by the experienced workman may be imparted to others in precise terms, which to the young beginner will be of invaluable service. Much important information may by these means be stored up, and at any time reference can be made to the experience of the past, which will then run no risk of being lost through disuse, inattention, or other causes.

The deterioration of templates or patterns of size, from their becoming worn or altered in process of time, is productive of great inconvenience, as many of us perhaps have experienced. For when an original standard was thus altered, it was irretrievably lost, because there were no means of ascertaining and recording the exact

measure. It is of great importance to the manufacturer who makes parts of machines in large quantities to have the means of referring to an accurate fixed measure: it will enable him to reproduce at any time a facsimile of what he has once made, and so preserve a system of sizes of the fitting parts unaltered. The greatest care should be taken to make standards of size correctly at first, and to preserve them unaltered. Errors in the standards are not only propagated in the copies, but are superadded to the errors in the workmanship, which will occur in the course of manufacture; and this is especially likely to occur in cases where one manufacturer supplies parts of machines for the use of another.

My argument is shortly this:—If we had a better system of notation for our measures, in which small differences in size were expressed in terms conveying their value to the mind, the importance of minute and accurate measurements would become more familiar, more appreciated, and more generally applied. Many operations would by that means be more easily and effectually performed, and in some cases greater safety will be the result. Take for instance the present method of proving guns, which are proved by firing them with a considerable charge of powder and shot. If the barrel

stands the proof without manifest injury, it is passed as a good one, while it may in the very process of proof have received such permanent injury as to render it highly dangerous for use. How much better it would be after proving the barrel to measure it, and ascertain accurately if any, and what, permanent alteration had taken place, and retain or reject it accordingly. This would be substituting an exact and satisfactory system for an uncertain and dubious trial; but, inasmuch as the degrees of alteration will be various, and the differences in their measurement very minute, a better system of notation with the improved mode of measuring is required, to enable this and other similarly useful applications to be made.

After careful thought and a comparison of different scales, I have come to the conclusion that the scale for standards of size given in the accompanying Table is the one I would recommend to be adopted. I have endeavoured to arrange one which would be easily intelligible to the ordinary workman, and that would in every possible case coincide with the old system, so as not to cause more expense in altering the present sizes than may be absolutely necessary. I am perfectly aware that other scales may be devised more complete and more advantageous in many respects, if we were now prepared not merely to

revolutionise, but to abandon what has been manufactured and is now in use. But would not that be going too far? As long as the machines already made are in existence, the sizes of their parts cannot be abandoned; and these considerations have induced me to propose a scale which shall combine the greatest possible advantages with the least possible change.

It would be desirable that those establishments which may decide upon adopting the decimal scale should introduce rules having the inch divided into tenths and their subdivisions, which would soon become as familiar to the workman as the eighth scale he now uses.

The scale proposed for the wire-gauge commences with the smallest size and increases by thousandths of an inch up to half an inch. Contrary to the custom usually adopted in marking the wire-gauge, I have called the smallest size No. 1, being 1-1000th of an inch, No. 2 being 2-1000ths of an inch, and so on; increasing up to No. 20 by 1-1000th of an inch between each number; from No. 20 to 40 by 2-1000ths; from No. 40 to No. 100 by 5-1000ths of an inch. I propose therefore to suppress the use of the numbers of designation which have been hitherto employed for the various wire-gauges, and simply call the sizes by their expressive

numbers in thousandths of an inch, as shown in the accompanying table of wire-gauges; a change which will, I think, render the new scale easily intelligible and convenient for use.

STANDARDS OF SIZE.			WIRE-GAUGE.						
Proposed Standards of Size for Taps and Dies.			Standard Wire-Gauge.		Old Birmingham Wire-Gauge.	Old Lancashire Wire-Gauge.	Old Metal or Plate-Gauge.	Old Needle Wire-Gauge.	Old Music Wire-Gauge.
No. of Screw Threads per Inch.	Old Sizes.	New standards of Size. Decimals of an Inch.	Value of each No. in Decimals of an Inch.	New Nos. of Gauge. Thousandths of an Inch.	Old Nos. of Gauge corresponding to New Nos.	Old Nos. of Gauge corresponding to New Nos.	Old Nos. of Gauge corresponding to New Nos.	Old Nos. of Gauge corresponding to New Nos.	Old Nos. of Gauge corresponding to New Nos.
48		·100	·001	1					
40	1/8	·125	·002	2					
32		·150	·003	3					
24		·175	·004	4	36		1	19	
24		·200	·005	5	35		2	18	
24		·225	·006	6	..		..	..	
20	1/4	·250	·007	7	34		..	17	
20		·275	·008	8	33		3	16	
18		·300	·009	9	32		..	15	
18		·325	·010	10	31		4	14	
18		·350	·011	11	..	..	..	..	
16	3/8	·375	·012	12	30	..	5	13	
16		·400	·013	13	29	80	6	12	
14		·425	·014	14	28	79	..	11	
14		·450	·015	15	..	78	7	..	
14		·475	·016	16	27	77	8	10	
12	1/2	·500	·017	17	..	..	..	..	
12		·525	·018	18	26	76	..	9	6
12		·550	·019	19	..	75	9	..	7
12		·575	·020	20	25	..	..	8	8
12		·600	·022	22	24	74	..	7	10
11	5/8	·625	·024	24	23	72	10	6	12
11		·650	·026	26	..	71	..	..	13
11		·675	·028	28	22	70	11	5	14
11		·700	·030	30	..	68	..	..	15

10	$\frac{3}{4}$	·750
10		·800
9	$\frac{7}{8}$	·875
9		·900
8	1	1·000
7	$1\frac{1}{8}$	1·125
7	$1\frac{1}{4}$	1·250
6	$1\frac{3}{8}$	1·375
6	$1\frac{1}{2}$	1·500
5	$1\frac{5}{8}$	1·625
5	$1\frac{3}{4}$	1·750
$4\frac{1}{2}$	$1\frac{7}{8}$	1·875
$4\frac{1}{2}$	2	2·000
$4\frac{1}{2}$	$2\frac{1}{8}$	2·125
4	$2\frac{1}{4}$	2·250
4	$2\frac{3}{8}$	2·375
4	$2\frac{1}{2}$	2·500
4	$2\frac{5}{8}$	2·625
$3\frac{1}{2}$	$2\frac{3}{4}$	2·750
$3\frac{1}{2}$	$2\frac{7}{8}$	2·875
$3\frac{1}{2}$	3	3·000
$3\frac{1}{4}$	$3\frac{1}{4}$	3·250
$3\frac{1}{4}$	$3\frac{1}{2}$	3·500
3	$3\frac{3}{4}$	3·750
3	4	4·000
$2\frac{7}{8}$	$4\frac{1}{4}$	4·250
$2\frac{7}{8}$	$4\frac{1}{2}$	4·500
$2\frac{3}{4}$	$4\frac{3}{4}$	4·750
$2\frac{3}{4}$	5	5·000
$2\frac{5}{8}$	$5\frac{1}{4}$	5·250
$2\frac{5}{8}$	$5\frac{1}{2}$	5·500
$2\frac{1}{2}$	$5\frac{3}{4}$	5·750
$2\frac{1}{2}$	6	6·000

·032	32
·034	34
·036	36
·038	38
·040	40
·045	45
·050	50
·055	55
·060	60
·065	65
·070	70
·075	75
·080	80
·085	85
·090	90
·095	95
·100	100
·110	110
·120	120
·135	135
·150	150
·165	165
·180	180
·200	200
·220	220
·240	240
·260	260
·280	280
·300	300
·325	325
·350	350
·375	375
·400	400
·425	425
·450	450
·475	475
·500	500

21	66	..	4	15
..	64	12	..	17
20	62	13	3	18
..	61	..	..	19
19*	59	14	2*	20*
..	56	15*	1	
18	55	16		
..	54	17*		
17*	52	18		
16	51	19		
15*	49	21*		
..	47	22		
..	45	24*		
14*	43	..		
..	42	..		
13	41	25		
..	38	26**		
12	34	27**		
11	31*	28		
10	29	31*		
9*	23	34*		
8	19	36*		
7	13			
6**	5			
5	2			
4*	C			
3	G			
2**	K			
1	N*			
..	P*			
..	S*			
00**	V*			
..	X**			
000				
0000**				

NOTE.—These Nos. correspond exactly or within ·001 inch with the new proposed Nos., except those marked *, which are within ·002 inch, and those marked **, which are beyond ·002 inch.

RIFLED FIRE-ARMS.

RIFLED FIRE-ARMS.

FIRE-ARMS are rifled to give rotation to the projectile round its axis of progression, in order to insure a regular and steady flight, the first thing therefore to be considered is what are the best mechanical means of effecting this object.

It would be foreign to our purpose to consider any of the various plans which have been proposed for furnishing the projectile itself with vanes, wings, grooves, or other configurations intended to give it rotation during its passage through the air. The only practical method hitherto adopted has been to make the barrel of a fire-arm of such a shape in its interior, that the projectile while being propelled from

the breech to the muzzle may receive a rotatory combined with a forward motion.

The system of rifling by grooves is the one that has been generally employed, and many experiments with different numbers of grooves, some of varying depths being deeper at the breech, and with different turns, some increasing towards the muzzle, have been tried and thought advantageous at various times.

The Enfield rifle has three grooves, with a pitch of 6 feet 6 inches, so that the bullet receives half a turn round its axis while moving through the barrel, the length of which is 3 feet 3 inches. The bullet, as is well known, is cylindro-conoidal, it is wrapped in paper and made of such a diameter as to pass easily down the barrel. It requires very pure lead to allow of its being properly expanded or "upset," by the explosion, and is driven partly against the original portions of the bore, called the lands, and partly in the form of raised ribs is forced into the grooves, whose spiral shape gives the required rotation. *See figure* A.

In the system of rifling which I have adopted the interior of the barrel is hexagonal, and, instead of consisting partly of non-effective lands and partly of grooves, consists of effective rifling surfaces. The angular corners of the hexagon are always rounded, as shewn

Fig. A.

Enfield *Bullet*

Fig a.

Fig. B.

Hexagonal of the weight used *Bullet in the service*

Fig. b.

Fig. C.

Section of Cylindrical Bullet in hexagonal Barrel.

Day & Son Lith.rs to the Que

in section by figure C. Either cylindrical or hexagonal bullets may be used. *See figures* B, b. Supposing a bullet of a cylindrical shape to be fired, when it begins to expand it is driven into the recesses of the hexagon, as shown in figure C. It thus adapts itself to the curves of the spiral, and the inclined sides of the hexagon offering no direct resistance, expansion is easily effected.

It is most important to observe, that with all expanding bullets proper powder must be employed. In many cases this kind of bullet has failed, owing to the use of a slowly-igniting powder, which is desirable for a hard metal projectile, as it causes less strain upon the piece, but is unsuitable with a soft metal expanding projectile, for which a quickly-igniting powder is absolutely requisite to insure a complete expansion, which will fill the bore. Unless this is done the gases rush past the bullet, between it and the barrel, the latter becomes foul, the bullet is distorted, and the shooting must be bad. With regard to fouling, it may be prevented by using a proper quantity of lubricating substance, of the right kind and adapted to the temperature of the weather, and a proper charge of powder of the right quality.

If the projectile used be made of the same hexagonal shape externally as the bore of the

barrel internally, that is, with a mechanical fit, metals of all degrees of hardness, from lead, or lead and tin, up to hardened steel, may be employed, and slowly-igniting powder, like that of the service, may be used.

Having noticed the form of interior which provides the best rifling surfaces, the next thing to be considered is the turn, that is, the proper curve which the rifled barrels ought to possess in order to give the projectile the necessary degree of rotation; this, in all cases must be sufficient to keep the projectile with its point foremost.

The Enfield rifle, with one turn in 6 feet 6 inches, causes the bullet, on issuing from the muzzle, to rotate once on its axis in six and a-half feet. This moderate degree of rotation only admits of short projectiles being used, as long ones turn over on issuing from the barrel, and at long ranges, the short ones become unsteady.

With the hexagonal barrel, I use much quicker turns, and can fire projectiles of any required length, as with the quickest that may be desirable they do not "strip." I made a short barrel with one turn in the inch (simply to try the effect of an extreme velocity of rotation) and found that I could fire from it mechanically-fitting projectiles made of an alloy of lead and tin, and with a charge of 35 grains

of powder they penetrated through 7 inches of elm planks.

At first I was desirous of using, if possible, the turn adopted for the Enfield Rifle, for firing long projectiles, and I tried various shapes and combinations of metal, so as to place the centre of gravity in different positions more or less forward; but when they were fired, the marks left by their passage through a paper screen, placed about 6 feet from the muzzle of the rifle, showed that they all turned over within that distance, because the rotation given by that comparatively slow turn invariably proved insufficient to keep them point foremost. For an ordinary military barrel, 39 inches long, I proposed a ·45-inch bore, with one turn in 20 inches, which is, in my opinion, the best for this length. The rotation is sufficient, with a bullet of the requisite specific gravity, for a range of 2,000 yards. The gun responds to every increase of charge, by giving better elevation, from the service charge of 70 grains up to 120 grains; this latter charge is the largest that can be effectively consumed, and the recoil then becomes more than the shoulder can conveniently bear with the weight of the service musket.

The advocates of the slow turn of one in 6 feet 6 inches consider that a quick turn causes

so much friction as to impede the progress of the ball to an injurious, and sometimes dangerous degree, and to produce loss of elevation and range; but my experiments show the contrary to be the case. The effect of too quick a turn, as to friction, is felt in the greatest degree when the projectile has attained its highest velocity in the barrel, that is at the muzzle, and is felt in its least degree when the projectile is beginning to move, at the breech. The great strain put upon a gun at the instant of explosion is due, not to the resistance of friction, but to the *vis inertiæ* of the projectile which has to be overcome. In a long barrel, with an extremely quick turn, the resistance offered to the progress of the projectile as it is urged forward becomes very great at the muzzle, and although moderate charges give good results, the rifle will not respond to increased charges by giving better elevation. If the barrel be cut shorter an increase of charge then improves the elevation.

The use of an increasing or varying turn is obviously injurious, for besides altering the shape of the bullet it causes increased resistance at the muzzle,—the very place where relief is wanted.

Finding that all difficulty arising from length of projectiles is overcome by giving

sufficient rotation, and that any weight that may be necessary can be obtained by adding to the length, I adopted for the bullet of the service weight (530 grains) an increased length, and a reduced diameter, and obtained a comparatively low trajectory.* This affords very great advantages; less elevation is required and the path of the projectile lies more nearly in a straight line, making it more likely to hit any object of moderate height within range, and rendering mistakes in judging of distances of less moment. The great difficulty experienced in the use of the rifle for long distances arises from the utter incapability of any marksman to judge correctly the distances of objects far away; it can only be met by making the projectile move in a trajectory or path as low and level as possible, this is done by using the reduced diameter which offers to the resistance of the air a proportionally less area, so that a high velocity is attained, shortening thereby the time of flight, and the projectile is very much less deflected by the action of the wind.

While the ordinary grooved rifle depends upon the expansion of the soft metal projectile,

* The trajectory of a projectile being the curve it describes in its passage; its height is represented by a perpendicular from its highest part let fall on a horizontal plane passing though the rifle.

in the hexagonal system, rifling may be effected independently of expansion, by making the projectile of the same shape as the interior of the barrel: in other words, by having a mechanical fit between them. The projectile may be used naked, and be made of metal of any degree of hardness. The expansion principle may also be combined with an easy mechanical fit, so that a projectile of metal harder than lead, as an alloy of lead and tin, may be used, which, while it loads easily, will expand sufficiently to fill up the bore, and give more than double the penetration of lead.

This system thus admits of the employment of projectiles of different densities and varied shapes, suitable for special purposes. If for example it be required to fire through plates of iron, a flat-fronted projectile of steel of the form shown in figure E, will be employed. When the flat-fronted projectiles were fired in comparison with those having rounded fronts, like figure B, from the same barrel, and under precisely similar conditions as to range (500 yards), charge, and weight, the pointed projectiles were not found to possess any great practical advantages over the flat ones, for the elevation of the former was only a minute and a-half better than that of the latter.

It was satisfactory to find that so slight a

Fig. D.

Tubular hexagonal

Projectile

Fig. d

Section of tubular

hexagonal projectile

Fig. E

Flat fronted

Hexagonal projectile

Fig. e

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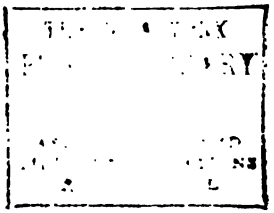

difference existed between the two shapes, for in other respects the flat-fronted projectile has many advantages. Besides being the form best adapted, as has been said, for firing against iron plates, it may be used for penetrating through water; in this respect I have succeeded in obtaining results which, while they are most important, were, I believe, previously considered unattainable. For firing through elastic materials, tubular projectiles, as shown in fig. D are used. They are fired with a wooden wad, and take out a core from the object perforated, leaving a corresponding hole which does not close up. The tubular projectiles also penetrate deeper into masonry than those of any other shape I am acquainted with.

The system of rifling which has been described with reference more particularly to small arms, is equally applicable to ordnance of all sizes. The principle of construction is simple and the extent of bearing afforded by the rifling surfaces provides amply for the wear of the interior of the gun; any requisite allowance for windage may be made at the same time that the projectile is kept concentric with the bore. When it enters the gun it bears upon a certain portion of each side of the hexagon, and when it comes out it bears on the opposite portion,—by easing off, therefore, that half of

each side on which the projectile bears as it enters, proper windage is allowed,—the other halves of the sides are left to preserve a full extent of bearing surface as it comes out, and at the same time maintain its concentricity with the bore. This plan of providing for windage obviates the great evils which arise from eccentricity in the case of spherical shot.

The effect of a proper rifling turn, which varies according to the bore and length of the piece, produces, as has been before shewn,* no loss of elevation while the rotation given to the shot adds greatly to its destructive power.† The practice obtained from an ordinary 9-pounder brass field gun, rifled by me, proves that, with a charge of powder one-third less than the service charge, the range was one-half greater than that of the same gun with spherical shot.

In comparing the strain upon a rifled cannon with that upon a smooth bore, the work done by the respective pieces must be taken into consideration. If the full powers of the former are to be exerted, and, if the extreme ranges

* See Ante p. 78. Out of a 24-pounder howitzer, having a turn of one in forty inches, I fired, with low charges, shells 10 diameters in length.

† When a rifle cannon shot enters into a ship, and strikes at an angle, it is deflected from object to object and sweeps round inside the ship, going through or tearing everything it encounters.

which it is capable of giving are required, a proportionally greater strain will be put upon the piece on account of the elongated form of the shot, and more strength is therefore required.

The mode of making large iron guns, by casting them in solid masses (as at present), is highly objectionable, and is certainly not suitable for bearing the full strain of a rifled gun. It is well known that if iron be cast in large masses, great irregularities will be produced in the metal during the process of cooling; and, beyond a certain limit, little or no increase of strength is gained by increasing its thickness.

Improved modes of construction can, however, be adopted, which will admit of the gun being loaded at the breech when required, and will give all the strength necessary for as large a charge of powder as can be consumed with the projectile intended for the piece. It is clear that every gun should have that amount of strength as a minimum standard.

In the construction of rifle cannon many things have to be considered in relation, and often in antagonism to each other, as the weight and length of the piece,—the diameter and weight of the projectile, the charge, the amount of rifling turn, and it sometimes happens that an advantage in one respect can only be gained by submitting to disadvantage in another.

The amount of turn to be given must be considered with relation to the charges intended to be used and the length of the gun, but should be as quick as possible, since the extent of true steady flight, in the case of a long projectile, depends on the rotation given to it For a great range, length of gun is requisite, as it provides for the consumption of large charges of powder, but the quick turn, which is so desirable, limits the length that can be used. The best combinations and proportions can only be arrived at after careful experiment.

I would observe, before concluding this paper, that it has been drawn up rather with the view of offering some reply to many inquiries, than with the intention of giving a detailed account of what has been done, or of presenting a complete treatise on the subject.

NOTE.—It is right to state that, from the time I first undertook, at the solicitation of the Government, to render what assistance I could in the improvement of rifled arms; I have always devoted my time and attention to them, without any remuneration whatever, even for personal expenses. The sums required have been advanced by myself; periodical accounts are sent in to the Government, and the advances have been repaid at its convenience.

APPENDIX.

NEW YORK INDUSTRIAL EXHIBITION, 1853.

OFFICIAL REPORT.

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NEW YORK INDUSTRIAL EXHIBITION IN 1853.

Special Report of Mr. Joseph Whitworth.

Having been unavoidably prevented, as explained in the General Report of the Commission,* from making a report upon the Machinery exhibited in the New York Industrial Exhibition, I have drawn up in a concise form the results of observations made while visiting the principal seats of those manufactures which came within my department.

The statement thus prepared embraces a variety of subjects, somewhat miscellaneous in their character, and which do not conveniently admit of a regular classification. I have endeavoured, however, as far as possible, to overcome this difficulty, and to adopt an arrangement by which the substance of the information

* This arose from the incomplete state of this department of the New York Exhibition up to the time when I left the United States.

which I collected may be distinctly and fully appreciated. This Report does not affect to embrace the whole scope of American manufactures, nor even to exhaust the interest of those particular departments upon which it touches; it is merely intended to direct attention to such facts connected with the machinery of the United States as came within my observation, and which it appeared desirable should be known to those engaged in mechanical and industrial pursuits in this country.

To the general reader many of the descriptions of manufacturing processes will, I am aware, be uninteresting, and in some cases, perhaps, unintelligible; for, looking to the persons for whose information I have more immediately written, I have thought it proper to adhere to those technical terms which are in use among men who are more or less acquainted with the application of mechanical science. For instance, when in describing a cotton mill in America, I have said, "One man can attend to a mule containing 1,088 spindles, each spinning 3 hanks, or 3,264 hanks on the average per day," I am aware that I am using technical language incomprehensible to the ordinary reader, but these few words convey all the requisite information to those practically acquainted with the subject. I have not, therefore,

attempted to impart a popular tone to the Report; and the very few general reflections which I have ventured to offer, are given at its close.

Some works have been noticed for their novelty and interest, others for their practical utility as affecting our native industry, and in some instances the information which I have collected has been directed to convey a general idea of the extent to which particular branches of manufactures are developed, of the conditions, as to management, under which they are carried on, and of the causes to which their flourishing condition is chiefly due.

The accidental absence of principals at the period of my visits, the limited time at my disposal, and my anxiety to embrace as wide a field of observation as possible, have severally constituted impediments where more minute information might have seemed desirable; but whatever may be the defects of this necessarily imperfect Report, I desire to record my sincere acknowledgments for the great courtesy and the kind attention which I received on all hands during my visit to the United States; I am the more bound to do so as the plan which I have pursued has precluded me from mentioning the names of many gentlemen who so greatly facilitated the objects of my visit, by showing me

over their own establishments, accompanying me to those of others, and affording me all the information in their power.

CHAPTER I.

Steam Engines and Machinery.

NEW YORK, PHILADELPHIA, BALTIMORE, PITTSBURGH, BUFFALO, BOSTON, LOWELL, LAWRENCE, HOLYOKE, WORCESTER, HARTFORD, AND SPRINGFIELD.

1. *Number of Establishments visited.* — The vast resources of the United States are being developed with a success that promises results whose importance it is impossible to estimate.

This development, instead of being, as in former cases, gradual and protracted through ages, is, by the universal application of machinery, effected with a rapidity that is altogether unprecedented.

Upwards of thirty establishments visited in different parts of the States, and employing in the aggregate from 6,000 to 7,000 men, afforded direct evidence that the greatest energy and

attention are brought to bear upon the manufacture of machinery.

2. *Marine Engine Works.* — The principal marine steam engine works are in New York, but there are large establishments of a mixed character in almost every town of importance; to particularise these and to give a full description of each is unnecessary. They are similar in character, and it frequently happens that it is only in some of the details that there is anything to remark upon. The practice which prevails of combining various branches of manufacture in the same establishment, would also render separate descriptions of each somewhat complicated. For instance, in some cases the manufacture of locomotives is combined with that of mill gearing, engine tools, spinning and other machinery. In others, marine engines, hydraulic presses, forge hammers, and large cannon were all being made in the same establishments. The policy of thus mixing together the various branches is objectionable; but the practice doubtless arises, in addition to other causes, from the fact that the demand is not always sufficient to occupy large works in a single manufacture.

Wherever facilities of carriage or other causes render it practicable to confine establishments to a special branch the most advan-

tageous results ensue. This was very evident in numerous and striking instances, which will be hereafter noticed.

It is to the introduction of railroads that the advantageous subdivision of manufactures is to be chiefly ascribed. The operations of large establishments are no longer confined to particular localities; the facilities of transport being so great, they are enabled to supply their special products, not only to a district or a kingdom, but to the world at large.

It is evident that isolated notices of details made in various places must have a disconnected character, and it is, therefore, convenient to mention in separate paragraphs what appeared worthy of remark.

3. *Locality of Works. — Beam Engines.* — Nearly all the marine engine works in New York are conveniently situated on the water side, and have slips attached to their yards, where vessels may be moored. The rise and fall of the tide is generally so small as to obviate the necessity of docks. Steam engines having their beams above the deck, are commonly used for the river and ferry boats, and they have generally a very long stroke. The following are some of the dimensions of a beam engine of one of the New York river steamers :—

Length of stroke, 12 feet; length of beam, 24 feet; depth of beam in the middle, 10 feet. The form of the beam is that of an elongated parallelogram, the outer frame or skeleton is made in one piece of wrought iron, inside of which is fitted another frame of cast iron, carrying the axis.

4. *River Steamers for Shallow Waters.*—A steamboat running on the Ohio, from Pittsburgh to Cincinnati, had a pair of direct acting engines with 32-inch cylinders and 8 feet stroke. There was no main crank shaft connecting the two paddle wheels, but each engine worked its own wheel independently of the other. This arrangement enables the boat to be steered with greater facility round the sharp turns encountered in the tortuous course of the river. The framework and outer bearings of the paddle wheels are supported by suspension rods, which are, as it were, slung over beams, and framework strongly constructed, and fixed in the centre of the vessel. The main deck is 280 feet long, and 58 feet wide. The paddles are 38 feet in diameter, having twenty-four floats, 12 feet wide by 28 inches in depth. For shallow rivers, flat-bottomed steamers, propelled by a paddle-wheel at the stern, are commonly used. Two were being built of iron in New York, drawing only $2\frac{1}{2}$ feet of water,

which were intended for the passage across the isthmus of Panama by the Nicaragua route.

5. *Lake Steamers.—Propellers.*—A marine engine establishment at Buffalo was principally occupied in making engines for screw steamers intended for lake and river navigation. The propellers of those intended to run in shallow waters are made with four, and sometimes six blades, each, and revolve with rather less than half their diameter immersed in the water. The blades are made of wrought iron, and bolted on to a cast-iron boss, fitted on the propeller shaft, so that a blade broken or damaged by coming in contact with "snags," or other obstructions, may be easily replaced. Some of the dimensions of machinery in a lake boat, used for carrying cargo, are as follows: —The propeller is 16 feet in diameter, with a pitch of 17 feet 3 inches, making 60 revolutions per minute; the cylinders are 36 inches in diameter, with a 10 feet stroke, and the speed attained averages about eleven miles per hour. The vessel has an upper deck for the accommodation of about 60 passengers. Small high-pressure steam engines for flour mills, agricultural implements, and other machinery, are made in the same establishment.

6. *Caloric Engines.*—Ericsson's caloric en-

gines were undergoing repair and alteration in New York, with the view of making the heated air act alternately upon each side of the piston, similarly to steam in an ordinary engine. The bottom of the cylinder is made of wrought iron, and arched. The upper part, in which the piston works, is of cast iron, and is connected to the lower part by bolts; it was the lower portion which proved defective in strength.

CHAPTER II.

PROCESS OF CASTING, COOLING, ETC., RAILWAY WHEELS, AND ANNEALING—RAILROAD SPIKE MAKING—NAIL AND RIVET MAKING—CAST STEEL WORKS—ENGINE TOOLS.

PITTSBURGH, PHILADELPHIA, LAWRENCE, WORCESTER.

7. *Iron Castings.*—The iron castings in some of the establishments were very good, and cylinders from 8 to 14 feet in diameter were well bored, with a finishing feed of cut of about three-eighths of an inch per revolution, which is a

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width of cut at least three times as great as that ordinarily given in English works.

At Pittsburgh a large casting for a hydraulic press was cooled by the following method:— Water is introduced into the interior of the core by a pipe, which extends to the bottom, and fills it previous to casting. Provision is made for the escape of the air by making the core fluted.

When the metal is poured into the mould it immediately heats the water, which is then drawn off by an escape pipe at the top of the core, and a supply of cold water is continually running in at the bottom.

Heat is thus gradually taken from the mass, and the whole cools uniformly. The casting was 10 inches thick, and weighed 7 tons. It took from three to four days cooling.

The best charcoal pig iron was selling in Pittsburgh at $45 per ton, having risen within a short period from $30 per ton.

Major Wade, of Pittsburgh, has made many experiments on the tensile strength of this iron. He found that it required a force of 45,000 pounds to tear asunder a bar an inch square. Some of the results of his experiments have been published by the United States Government in the "Ordnance Manual."

8. *Pickling Castings.*—The process of "pick-

ling castings," as it is called, is performed in the following manner:—

The castings are placed on two wooden stages, covered with lead, each being 20 feet by 12 feet wide, and supported by two rollers, about 18 inches from the floor.

The trough containing the pickle (which consists of $2\frac{1}{2}$ parts of water to 1 of acid) is of the same length as the stages, which are inclined towards it, to enable it to receive the drainings. The diluted acid is poured over the castings by hand from a long ladle, and when they are dry, the operation is repeated as often as necessary.

The stages are then inclined in the opposite direction, and cleansed from the coating of acid and sand by a powerful stream of water directed upon them from a hose pipe.

In England when the process of pickling is adopted for light castings, it is usual to immerse them in the liquid. The American method was probably adopted in consequence of the high price commanded by manual labour.

9. *Annealing Railway Wheels.*—The leading and trailing wheels of locomotives, and railway carriage wheels, are commonly hollow cast-iron disc wheels.

The process of annealing adopted in a large manufactory in Philadelphia is as follows:—

The wheels are taken from the moulds, as soon after they are cast as they can bear moving without changing their form, and before they have become strained while cooling. In this state they are put into a circular furnace or chamber, which has been previously heated to a temperature about as high as that of the wheels when taken from the mould; as soon as they are deposited in this furnace or chamber, the opening through which they are passed is covered, and the temperature of the furnace and its contents is gradually raised to a point a little below that at which fusion commences. All the avenues to and from the interior of the furnace are then closed, and the whole mass is left to cool gradually as the heat permeates through the exterior wall, which is composed of fire-brick $4\frac{1}{2}$ inches thick, inclosed in a circular case of sheet iron $\frac{1}{8}$ inch thick.

By this process the wheel is raised to one temperature throughout before it begins to cool in the furnace, and, as the heat can only pass off through the medium of the wall, all parts of each wheel cool and contract simultaneously. The time required to cool a furnace full of wheels in this manner is about four days.

By this process wheels of any form, and of almost any proportions, can be made with a solid nave.

The manufacture of these wheels was commenced in 1847, and in 1850, 15 tons weight were cast per day. The foundry and works as now completed are calculated to turn out 40 tons per day.

In another establishment the wheels while hot are lifted from the mould, and the centre part is placed in a hole communicating by means of a flue with a high chimney, and the edge is packed round with sand. A draft is thus created which cools the mass of iron near the centre of the wheel, and in some measure prevents it from contracting unequally during the operation.

At a foundry in Worcester, Connecticut, the wheels when cast were taken hot from the moulds, and immersed in a pit of white sand, where they are left to cool gradually.

In order to obtain the best chill, it is considered necessary to use cold blast iron made with charcoal.

10. *Railroad Spikes.* — There is a large demand for railroad spikes in the United States.

On nearly all the railroads the rails are laid on transverse wooden sleepers, and are simply fastened down by large iron spikes with projecting heads, except at the junction of two rails, where the ordinary chair is employed.

In a manufactory at Pittsburgh, a machine

was at work which made these spikes, each weighing ½lb., at the rate of 50 per minute. They are packed in kegs, each containing 300. Seven men only are employed on the works, and they manufacture 5 tons of spikes per day.

11. *Nails and Rivets.*—In another establishment at Pittsburgh, 250 men are employed in manufacturing bar iron, rods, sheets, and nails. The iron is manufactured both with anthracite coal and charcoal.

They have fifty-one machines for making cut nails; many of them are self-acting in the feeding for the smaller sizes; the strip of iron is inserted in a tube, which is made to revolve alternately half round each way.

They make 2,000 kegs of such nails per week, each weighing 100 lbs., and containing sizes from fourpenny up to tenpenny nails.

A rivet-making machine was at work, which made rivets weighing seven to the pound, at the rate of eighty per minute. Its main shaft carried two cams, one a side cam which gave the motion for cutting off and holding the iron between the dies, the other a direct cam for forming the head of the rivet.

The cams for the nail machines are made of chilled cast iron, and that part of the lever which acts against the cam is faced with a plate of

bell-metal. Several large grinding-stones were used, having mouldings on their peripheries for restoring the dies when worn.

It is usual in England to soften the dies by annealing, previous to restoring their shape, and again hardening them subsequently. The shape may be thus more perfectly restored but at a greater cost, and the operation of softening and re-hardening deteriorates the quality of the steel.

12. *Cast Steel.*—The manufacture of cast steel is not carried on to any great extent. Some works have been started in Pittsburgh, which have hitherto met with great difficulties, but they are now more successful.

Workmen were obtained from Sheffield, but they were intractable, and failed to give satisfaction to their employers.

There were two converting and nine melting furnaces, producing upwards of 2,000 lbs. per day.

The steel sells at $17\frac{1}{2}$ cents per lb. ($8\frac{3}{4}d.$).

13. *Engine Tools.*—The engine tools employed in the different works are generally similar to those which were used in England some years ago, being much lighter, and less accurate in their construction, than those now

in use, and turning out less work in consequence.

The proportion of slide to hand lathes is greater than in the generality of English workshops.

Planing and drilling machines are commonly used; but there are comparatively very few horizontal or vertical shaping machines, and a considerable amount of hand labour is, therefore, expended on work which could be performed by machines much more economically.

The foundries are, for the most part, large and well arranged, and are furnished with good powerful cranes.

Great anxiety is now manifested by many manufacturers to have engine tools of a better description than those in use; and before long there will, no doubt, be great improvement in this respect.

CHAPTER III.

BUTTONS—DAGUERREOTYPE FRAMES—PINS—HOOKS-AND-EYES—CUTLERY, ETC.

WATERBURY.

14. *New Manufacturing Towns.*—The energetic character of the American people is nowhere more strikingly displayed than in the young manufacturing settlements that are so rapidly springing up in the Northern States.

A retired valley and its stream of water become in a few months the seat of manufactures; and the dam and water-wheel are the means of giving employment to busy thousands, where before nothing more than a solitary farm-house was to be found. Such, in a few words, is the history of Waterbury and all the Naugatuck settlements of Holyoke, Chicopee, Lowell, and Lawrence. Many others might be mentioned, but allusion is now only made to those visited.

15. *Waterbury.*—Waterbury is situated in the Naugatuck valley, about 24 miles north of New-haven. It contains many manufacturing estab-

lishments, carried on principally by joint stock companies. Besides other firms, there are twenty-eight companies, of which the greater number are employed in the manufacture of rolled and sheet-brass, copper, wire buttons, German silver, pins, cutlery, hooks-and-eyes. The others are employed in manufacturing hosiery, felt, cloth, webbing, covered buttons, umbrella trimmings, leather, &c.

The official statements of these companies show that their respective capitals vary in amount to a very great extent, and that they are in some cases remarkably small :—

There are	2 with a capital of	$6,000 (about £1,200).
	5 between	$10,000 (£2,000), and $20,000 (£4,000).
	13 - -	$20,000 - - - $100,000 (£20,000).
And the rest	- -	$100,000 - - - $253,000 (£50,000).

Great facilities are afforded in many of the States for the formation of manufacturing companies. The liabilities of partners not actively engaged in the management are limited to the proportion of the capital subscribed by each, and its amount is published in the official statements of the Company. In the case of the introduction of a new invention, or a new manufacture, the principle of limited liability produces most beneficial results. Persons who from their connections or occupations are likely to be interested in, or profited by, the new invention or manufacture, readily associate together and subscribe

capital to give the new proposal a fair trial, when they are assured that their risk will not extend beyond the amount of which they may choose to contribute.

The cost of obtaining an act of incorporation is very trifling; in one case where the capital of the company amounted to $600,000 (120,000*l.*), the total cost of obtaining the act of incorporation was 50 cents (2*s.* 1*d.*).

16. *Button Machinery, Buttons, &c.*—Upwards of 200 men are employed by one of the companies in the manufacture of buttons, hinges, daguerreotype plates and frames, &c.

The round-shaped button is formed by two punches, one working inside the other, each being driven by a separate eccentric, and the inside punch having the longer stroke. By this arrangement the disc is forced through the die, and drops into a box, thus saving the labour of picking out, which is necessary where a single punch and solid die are used.

The spindle of the polishing lathe in which the button is fixed whilst being burnished, makes 10,000 revolutions per minute.

17. *Daguerreotype Frames.*—The lathe in which the oval frames used as settings, for daguerreotypes, are turned, has an oval chuck,

and a stationary cutting tool fixed to the slide rest, for "trueing out" the previously punched oval. Two milling tools are used, one for forming the bevilled edge, the other for ornamenting the face of the oval frame.

The milling tool, as it revolves, is allowed to swivel so as to accommodate itself to the oval. When the bevilled edge has been formed, the first milling tool is removed and another substituted while the work revolves.

One workman is able to turn, and ornament by milling, two gross of frames per day.

18. *Pin and Hook-and-eye Manufactory.*—No description of the machines used in pin making can be given, as the process of "papering" is all that is permitted to be seen.

The pins are all papered by machinery; they are placed in a shallow feeding dish in an inclined position, so as to allow them to descend gradually as they are shaken by a quick vibratory motion. They fall from the spout of the feeding dish upon the centre of an inclined shallow trough, about 18 inches long, through which runs lengthwise a slit sufficiently wide to admit the shank of a pin, and yet suspend it by its head. It being a matter of chance, when a pin falls from the spout, whether it will drop into the slit or slide down the trough, a sufficient

number are allowed to descend to insure the filling of the slit by those which happen to fall favourably.

The superfluous pins slide down into a box, from which they are again lifted from time to time to the upper feeding dish. The descending line of suspended pins is conducted by the slit (which is curved at its lower end) to a sliding frame which is worked by the woman who attends the machine.

The frame carries a dozen grooves, and in each of these a pin is deposited as it passes under the slit; the pins are thus arranged in a row, with their points all turned the same way. The sheet of paper for receiving them is placed by the attendant on a grooved table, and deep folds are pressed into it at equal distances, and into the cross ridges thus formed a row of pins is pushed by the carrying frame at every thrust forward.

Under no circumstances whatever are strangers allowed to enter the rooms in which the pin-making machines are at work. The workmen employed are obliged to enter into a bond, and find two sureties that they will not disclose anything relative to the machinery. The company preferred keeping their mode of operation secret in this way to taking out a patent.

19. *Hook-and-eye Making.*—Three different descriptions of machines are employed in making hooks-and-eyes,—the wire being let in on one side of the machine, and a completed hook or eye dropped out on the other.

The machines appeared to make them at the rate of about 100 per minute.

About eighty hands are employed, who are said to make 1,200 packs of pins, each containing 3,360 pins, and 2,500 gross of hooks and-eyes, per day.

20. *Cutlery.*—The cutlery and file works were conducted on a limited scale. Many beautifully finished knives were exhibited, and were said to command a higher price than those of a similar class imported from England.

The artizans are employed principally on piece-work.

In the cutlery department a workman was pointed out who earned $70 (about 14*l.*) per month, while the earnings of others occupied on precisely the same kind of work only amounted to $30 (6*l.*) per month.

Thus it will be seen that each workman does the best he can for himself, irrespective of others, and reaps the reward due to his superior skill and industry.

CHAPTER IV.

Locks—Porcelain Handles—Clocks—Pistols and Guns.

PITTSBURGH. NEWHAVEN, WORCESTER, HARTFORD.

21. *Lockmaking.*—The manufacture of locks appears to be rapidly extending. In an establishment at Pittsburgh, employing 350 men in making locks, coffee mills, copying presses, &c., good work was being turned out.

Another at Newhaven, Connecticut, employs about 200 men in making locks and lock-handles. The latter are made of coloured clays, so mixed as to present a grained appearance. They are first moulded by hand, then turned in a self-acting lathe with great rapidity, and are afterwards baked in a furnace.

Padlocks are made here of a superior quality to those of the same class ordinarily imported from England, and are not more expensive.

22. *Clockmaking.*— The celebrity attained by New England in the manufacture of clocks

gives a peculiar interest to a visit to one of the oldest manufactories of Connecticut; 250 men are employed, and the clocks are made at the rate of 600 per day, and at a price varying from $1 to $10, the average price being $3.

The frames of the clocks are stamped out of sheet brass, and all the holes are punched simultaneously by a series of punches fixed at the required distances.

The wheels also are stamped out of sheet brass, and a round beading is raised by a press round their rims for the purpose of giving them lateral strength. They are cut by a machine having three horizontal axes, carrying each a cutter placed about 4 inches apart. The first cutter is simply a saw, and the second rounds off the teeth. In cutting an escapement wheel, the first cutter is made to cut each tooth entirely round, and then either the second or third axis with its cutter is used for finishing. The pullies on the three axes are driven by one driving pulley with three straps working over and in contact with each other.

The plates forming the clock faces, and other discs, are cut out by circular shears. The beaded rims intended to go round the clock faces, varying in size from 15 inches downwards, are stamped in concentric rings out of a disc, and

then made of the required form by means of dies and a stamping press.

The ogee form given to the wooden framing of the common clock is formed by a revolving cutter of the required shape, making 7,000 revolutions per minute, over which the piece of wood is passed by hand,—the requisite pressure downwards being given at the same time.

A circular cutter fixed on a horizontal axis is also used for roughly planing the back parts of the wooden clock. Its diameter is about 18 inches, and it has four lateral projections, carrying 4 cutters, 2 gouges, and 2 chisels. These revolve round a fixed circular centre plate, of about a foot in diameter, against which the work is pressed as it is passed along. Each clock passes through about sixty different hands: more than half of the clocks manufactured are exported to England, and of these a large portion are re-exported to other markets.

And it is worthy of remark, that the superiority obtained in this particular manufacture is not owing to any local advantages; on the contrary, labour and material are more expensive than in the countries to which the exportations are made; it is to be ascribed solely to the enterprise and energy of the manufacturer, and his judicious employment of machinery.

23. *Guns and Pistols.*—In a large manufactory at Hartford, from 400 to 500 men were employed in making revolving pistols at the rate of from 1,200 to 1,500 per week.

Self-acting machinery and revolving cutters are used for making all the separate parts, and the tools are made and repaired in a machine shop, which is attached to the works.

In another establishment at Worcester, Connecticut, 175 men were at work, manufacturing guns, rifles, and pistols. Revolvers were made in large numbers with barrels on the old principle, and were all proved by hydraulic pressure.

Further particulars will be given respecting this manufacture when the Government establishments are noticed.

CHAPTER V.

Wood Working.

LOWELL, BUFFALO, PHILADELPHIA, BALTIMORE, WORCESTER, NEWHAVEN.

24. *Labour-saving Machines.*—In no branch of manufacture does the application of labour-saving machinery produce by simple means more important results than in the working of wood.

Wood being obtained in America in any quantity, it is there applied to every possible purpose, and its manufacture has received that attention which its importance deserves.

It would be difficult to point in any country to a more successful application of machinery to the working of wood than was made in England long ago in the manufacture of ship blocks, by the late Sir Isambard Brunel, aided by the late Mr. Maudslay; other instances of mechanism most ingeniously adapted to similar purposes might also be cited. It cannot, therefore, be said that in England nothing has been done in

this branch of manufacture; but it must be confessed that the improvements which have been made have not been extended, as they might have been, to ordinary purposes, though, in this respect, a desire for progress is now evidently manifested.

A house in Liverpool is importing the best machines of the kind in use in America, and is making great efforts to introduce them generally in England.

25. *Saw Mills, Lowell.*—The trees sawn up in the Lowell saw mills are floated down from the interior of the country by river; they are docked in a basin in the timber yard, and are dragged up an inclined plane into the interior of the mill as they are wanted.

In an upper story are placed two large saw frames, and between them travels an endless chain running along the shop floor under pullies, and extending down the inclined plane nearly to the edge of the basin. To any part of this endless chain may be hooked another chain, which, being passed round one or more trees as they lie in the basin, drags them up into the mill and deposits them alongside the saw frames.

Shingles, used for covering the roofs and sides of houses, are made in vast quantities.

A circular saw cuts them 16 inches long, from

3 to 9 inches wide, and of a thickness tapering from $\frac{3}{8}$ to $\frac{1}{8}$ inch, at the rate of from 7,000 to 10,000 per day, according to the nature of the wood.

Timber is also cut up into laths 4 feet long, at the rate of from 60 to 100 per minute, by a circular saw attended by two men.

26. *Saw Mills, Buffalo.*—In these mills boards were sawn into "sidings," that is, long wedged-shaped boards for the sides or roofs of houses, by a circular saw, at the rate of 17 feet per minute. The board is introduced at the back of the saw, and moves in the direction in which it revolves. It thus cuts with the grain, and the strength of the cut assists the forward feeding motion of the board.

Subdivision of manufacture is advantageously adopted as a system.

Many works in various towns are occupied exclusively in making doors, window frames, or staircases by means of self-acting machinery, such as planing, tenoning, morticing and jointing machines. They are able to supply builders with the various parts of the woodwork required in buildings at a much cheaper rate than they can produce them in their own workshops without the aid of such machinery.

In one of these manufactories, twenty men

were making panelled doors at the rate of 100 per day.

Portable sawing machines, driven by horse-power, are commonly used for sawing up logs of wood for fuel, particularly at the various stations on the railroads, where the wood intended for the consumption of the locomotives is stored in piles.

The "horse-power machine" consists of a stout frame supporting a railway about 7 feet long, on which run the rollers of an endless travelling platform. The axles of the rollers are of iron, $\frac{5}{8}$ in. diameter, stretching across the rails, and are connected together by a series of links, each about 12 inches long, so as to form an endless chain, which passes over a fixed segment at one end and the chain wheels at the other. The travelling platform is made by planks of wood about 12 inches broad, $1\frac{1}{4}$ inches thick, fastened transversely to the endless chain. It is inclined at an angle of about 7° to the horizontal line, and the horse being placed on the platform, pushes it backward from under him, which causes the chain wheels at the end of the frame to revolve, and the motion thus obtained is conveyed to the circular saw or other machine required to be driven. Some horse-power machines are made to admit two horses abreast. They are found very useful to farmers; when

requisite, they are mounted on wheels, and may be easily taken from place to place to saw up trees which could not conveniently be moved entire.

27. *Planing Machines.*—A numerous variety of planing machines are in common use. For flooring boards, Woodworth's machine is found to answer very satisfactorily. In planing mills at Philadelphia, four of them were working in one room side by side; they have three cutters on each horizontal axis, having a radius of 6 inches, and making 4,000 revolutions per minute. The cutters are said to be capable of planing from 2,000 to 3,000 feet of work without being sharpened with the oil-stone, and from 20,000 to 30,000 feet without being ground.

They plane boards 18 feet long, varying in width from 3 to 9 inches, at the rate of 50 feet per minute. At the same time that the face of the board is planed, it is tongued and grooved by cutters revolving with a radius of about 3 inches, on vertical axes on each side of the board.

The chips made by the four planing machines are driven through large pipes, and fall into a trough about 20 inches wide, running across the room immediately under the cutters. In this trough works an endless chain, on which are fixed

wooden scrapers that carry along the chips as they fall, to a recess at the side of the room. Here they are carried off by the scrapers of another endless chain, running up an inclined plane. The pullies on which this side chain works are larger in dimensions than those of the transverse chain which works inside.

The transversing chain thus deposits its chips in the trough of the inclined plane, and they are carried up to a hole in the ceiling of the fuel room, adjoining the boiler house; through this hole they fall into the fuel room, and fill it up, of necessary, to the top.

28. *Daniel's Planing Machine.*—Where an accurately smooth surface is required, Daniel's planing machine is employed.

It consists of an upright frame, in which a vertical shaft revolves, having horizontal arms, at the ends of which are fixed the cutters.

The work is carried along on a travelling bed under the cutters, which are driven at a very high speed.

29. *Box Making.*—In a box manufactory at Worcester, Connecticut, a machine, made on Woodworth's principle, planed boards 10 inches wide simultaneously on both sides.

Boxes are made in great numbers, from

boards which are tongued and grooved by what is called a "matching machine," and then put together as that operation is finished.

The tonguing and grooving cutters are fixed on horizontal axes, and the workman passes the boards alternately over one or the other, as the sides require to be tongued or grooved.

Other varieties of planing machines are also in use, known by the names of their different inventors; some of them have fixed, vertical, or horizontal cutters, others vertical or horizontal revolving cutters, and various other combinations, according to the purposes for which they are intended.

30. *Spill or Match-making Machine.*—This machine makes 900 round spills, 15 inches long, $\frac{1}{8}$ inch diameter, per minute; so that if each spill were cut into five matches, each 3 inches long, 4,500 would be produced every minute.

The spills are cut from pieces of straight-grained timber, made of such a length as to pass between two grooved feeding rollers, which hold the timber, so that its under surface is level with the lowest parts of a row of tubular cutting tools, or long sharp-edged punches.

The cutting tools are thus arranged:—Five pieces of steel are fixed side by side in a horizontal bar. Each piece of steel is perforated

with three long holes, lying close together, and having their ends sharpened like the cutting edges of a hollow punch. A line of fifteen tubular cutters is thus formed, and motion is given to the horizontal bar, in which they are fixed by a crank, which impels them against the timber. This is depressed at each stroke sufficiently to allow each cutter to cut out its spill, which passes through and falls out behind.

The cost of this machine would not exceed 20*l.*, and when the number of matches, all nicely rounded, which it is capable of producing, is contrasted with the number which could be produced by a hand instrument in the same time, it will serve as a simple and striking illustration of the advantageous employment of machinery to do the work of man.

31. *Last and Boot-tree Manufactory.*— A machine, constructed on Blanchard's principle, is used for making lasts.

A pattern last, and the block of wood from which another last is to be cut, are fixed upon, and revolve round, a common axis, being connected with the centres of a headstock fixed on a frame made to oscillate from below. As the pattern revolves it is kept continually pressed against a knob of iron by a spring, and as the block of wood revolves it is shaped by a circular

cutter, revolving on a fixed axis, with its cutting edges in a line with the face of the knob. The pattern and the copy revolving simultaneously on a common axis, as the surface of the pattern is pressed against the projecting knob, the oscillating frame is made to move, so that the revolving cutters shape from the block a surface exactly corresponding to the surface of the pattern, and the copy occupies relatively to the cutters the same position which the pattern does relatively to the knob of iron.

About 18 men are employed, who make 100 pair of lasts per day, exclusive of boot-trees.

32. *Furniture Making.*—Labour-saving machines of all kinds, sawing, planing, boring, shaping, and jointing machines, are very advantageously employed in the manufacture of furniture. An apparatus of a very simple character is used for shaping the arms and legs of chairs.

Two vertical cutters are made to revolve in opposite directions, at the rate of about 1,700 revolutions per minute, on axes projecting above a bench.

The cutters are about 4 inches in diameter, and between them and the bench are loose washers or rollers, against which the pattern to which the work is fastened is pressed so as to guide the cut.

The cutters revolve in opposite directions, and the work may be pressed against either one or the other, so as to suit the cut to the direction of the grain of the wood, without the workman having the trouble of reversing its position.

33. *Agricultural Implements — Ploughs.* — Labour-saving machines are most successfully employed in the manufacture of agricultural implements.

In a plough manufactory at Baltimore eight machines are employed on the various parts of the woodwork.

With these machines seven men are able to make the wooden parts of thirty ploughs per day.

The handle pieces are shaped by a circular cutter, having four blades, similar to those of smoothing planes, fixed on a horizontal axis, with about two inches radius, and making nearly 4,000 revolutions per minute. The work to be shaped is fastened to a pattern, which is pressed against a loose roller on the axis of the cutter as the workman passes it along, and it is thus cut of exactly the same shape as the pattern.

All the ploughs of a given size are made to the same model, and their parts, undergoing similar operations, are made all alike. Some of the sharp edges of the wood are taken off or

chamfered by a cutter revolving between two cones; these guide and support the work as it is pressed down edgewise on the cutters, and passed along by the workman.

34. *Ploughs — (continued).*—The other machines in use consisted of a circular and vertical saw, and machines for jointing, tenoning, drilling, and for making round stave rods, and giving them conical ends, the whole being of a simple and inexpensive character.

The curved handle pieces of the ploughs, which require to be steamed and bent, are obtained already shaped from the forests where they are cut, and are advantageously supplied to the large manufacturers. The prices of the ploughs vary from $2\frac{1}{2}$ to $7. The price of—

Pig-iron in Baltimore was	$40 per ton.	
Pine timber - -	$20 per 1,000 feet.	
Ash - - -	$24	,,
Oak - - -	$25	,,

35. *Mowing Machines.*—In a manufactory at Buffalo, mowing machines were being made in large numbers, 1,500 having been supplied this summer.* Two were in operation in a field a

* The summer of 1853.

short distance from the town; each was drawn by two horses, and could mow on an average 6 acres of grass per day.

The machine is similar in its construction to the common reaping machine, but it has only one wheel, furnished with projections to prevent it from slipping. This wheel gives motion to the cutters, and supports one side, the other rests on a runner like that of a sledge. It has a pole to which two horses are attached in the ordinary way, and the driver sits on a seat fixed behind the cutters.

36. *Churn Making, &c.*—In an establishment at Worcester, Connecticut, 250 hands are employed principally in making ploughs, hay-cutters, churns, &c.

Templates and labour-saving tools are used in the manufacture of these implements, which are sold in very large numbers.

The churns consist of a double case, the inner one being of zinc, which receives the milk or cream, and in which the arms revolve, the outer one being of wood. It is found by experience that butter is formed most rapidly when the milk or cream is churned at a certain temperature, and in order to obtain this temperature, which is indicated by a thermometer inserted in the churn, warm or cold water is introduced

between the inner zinc and outer wooden casing as may be required.

37. *Carriage Making.*—Many of the carriages, especially those technically called "waggons," are made of an exceedingly light construction, and are intended generally to carry two and sometimes four persons.

Their wheels are frequently made with only two felloes, which are bent round by the operation of steaming, and are strengthened at the joining with iron clamps. The wheel of a carriage constructed to carry four persons had felloes only $1\frac{1}{2}$ inches square. They are generally made of white oak, and the spokes are obtained ready shaped from shops where their manufacture forms a special trade.

It would seem as if the elasticity of these carriages peculiarly fitted them for the very bad roads on which they in general have to run, and it is evidently a principle with the Americans to use up their light carriages and save their horses.

Every man in America who is able to keep his waggon is free to do so, unfettered and unquestioned, consequently their use is so general that it may be said to be almost universal. Their manufacture is one of great importance, and supports a vast number of

wheelwrights and artizans of that class, who from the nature of their employment attain great skill and aptitude, enabling them to turn their hands to almost any variety of work, and rendering them a most useful and important class.

CHAPTER VI.

Stone-Planing Works—Brickmaking from Dry Clay.

STATEN ISLAND, NEW YORK, WASHINGTON.

38. *Stone-planing Machines.*—In an establishment at Washington, which has but recently commenced operations, there were two planing machines, and a grinding or polishing machine. Considerable difficulties have hitherto attended the employment of machinery for planing stone such as granite, and stone of similar formation.

These difficulties have, however, been surmounted most successfully by the construction of planing machines such as are used in stone works in New York and Washington, in the former of which upwards of 400 men and ten machines are employed.

The planing machine consists of an upright frame, in which revolves a vertical shaft, carrying three horizontal arms. At the extremities of these arms are fixed circular cutters, inclined outwards about 45° from the perpendicular, or about the angle at which the workman would hold his chisel. They are about 10 inches in diameter, and $\frac{3}{4}$ inch thick, made of steel, and bevilled on both sides, leaving a sharp edge. They are fitted upon axes, and are at liberty to revolve loosely in their bearings as their edges strike the stone.

The cutters are carried round by the shaft at the rate of about eighty revolutions per minute when planing freestone, and sixty when planing granite.

The stone is moved forward on a bed to which it is keyed; the cutters strike its surface obliquely as they are carried round on the revolving arms, turning at the same time on their own axes, and chipping and breaking off the projecting portions of the stone at every cut.

The machine planed the face of a stone slab 4 feet long and 2 feet wide, in seven minutes.

Another modification of this machine, which is not so economical, is employed when it is necessary that the face of the stone be left in lines as it came from the tool.

The stone is keyed on a travelling bed, and

passed under a frame, in which works a sliding carriage driven by a crank; in this carriage is fixed the circular cutter at the required angle, and as the stone is carried along, the cutter is driven backwards and forwards across its face at right angles to the direction in which it moves, and chips off parallel breadths of stone at every cut.

The cutters can be used for planing from 300 to 400 square feet of freestone surfaces, and about 150 square feet of granite, without being ground.

39. *Stone Polishing Machine.*—The stone is polished by a flat circular disc of soft iron, which is made to revolve horizontally. The axis of a disc is fixed at the end of a heavy frame, which moves round a strong centre shaft in a radius of about 12 feet.

The polishing disc revolves at the rate of 180 revolutions per minute. It is driven by a strap, to which motion is given by a driving pulley, fixed on the centre shaft. The disc is guided, and its pressure regulated by hand. It will polish about 400 square feet of surface in a day of ten hours.

40. *Brickmaking with Dry Clay.*—A machine for making bricks from dry clay was in operation

on Staten Island, about nine miles from New York. The works are carried on under extensive sheds, near to the water side, and are connected with a wharf by a railway, which also extends to the bed from which the clay is dug. A large movable shed is erected on the bed of clay at the terminus of the railway.

In dry weather the clay is collected by slicing it from the surface with a kind of shovel having a sharp edge, which is drawn by two horses, and will hold about two barrowsful.

In wet weather the surface of the clay is harrowed to the depth of 2 or 3 inches by a triangular wooden frame, carrying nine teeth, a process which, in the powerful rays of an American sun, soon causes the moisture to evaporate. It is then taken off by the scoop or shovel above described, and conveyed to the shed, whence it is carried by rail to the machine shed. It is deposited close to a cylindrical screen, revolving on a fixed axis, which has projecting loose bars. The screen is about 8 feet long and 3 feet in diameter, and consists of bars $\frac{5}{8}$ inch square, rivetted on two cast-iron wheels, which form the ends; the bars are about $\frac{1}{16}$ inch apart, and the clay is riddled through them. The screen is inclined and the clay is fed in between the arms of the wheels, and as it revolves the small pulverized particles fall

through the bars, while the large stones pass out at the lowest end.

The clay is next raised by elevators, which are fixed to an endless leather belt about a foot wide, to the height of about 12 feet, and conveyed to rollers. It is ground and shovelled into hoppers which feed the moulds; these are 8 inches long, 4 inches wide, and 4 inches deep.

The clay is dropped into the moulds, which are placed six in a row, to the depth of 3 to $3\frac{1}{4}$ inches, according to the quantity of moisture it contains, and is afterwards compressed to the thickness of 2 inches in the following way:—

Six presses or rams, fixed in a heavy frame, are raised by a cam, and being allowed to fall, exert very great pressure by their impact on the clay. The blow is repeated, and then the bricks are powerfully compressed above and below by revolving cams; thirty-six bricks are made per minute. They are at once conveyed to the kiln, which is under the shed at a short distance from the machine.

After being burnt, they are separated into three shades of colour, of light and deeper reds. The best burnt bricks are equal in quality to the best English stocks, and were selling at $12 per 1,000.

41. *Brickmaking from Dry Clay* — (*con-*

tinued).—In a brickyard at Washington, Sawyer's machine, which had been in use for sixteen years, makes about 1,800 bricks per hour from dry clay by compression only.

The clay is obtained from a pit close by. As it is dug out it is carted up an inclined plane to the floor, over the room where the machinery is at work.

A roller weighing 1,600 lbs., and making sixty revolutions per minute, grinds it upon a grating through which the pulverized particles fall into the room below.

There it is shovelled into a hopper which supplies the brick moulds by feed-pipes. Three bricks are made at one time, being compressed by top and bottom pistons or pressers, which are connected together by long iron rods, and from the top part are suspended levers, with toggle joints worked by cranks. The bricks were sold at the rate of $6\frac{1}{2}$ dollars per 1,000, and were of a medium quality between English seconds and stock bricks.

CHAPTER VII.

INDIARUBBER MANUFACTORY—FISHING-NET-MAKING MACHINE—FLOUR MILLS—ELEVATORS.

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42. *Indiarubber Manufactures.*—Indiarubber is applied to a great variety of purposes, and its manufacture here is attended with very great success.

By the process of hardening, the substance becomes of the consistency of horn. It is manufactured into combs, walking sticks, and other articles.

43. *Indiarubber Overshoes.* — The indiarubber in its rough state is first cut up by shears into small pieces. It is then put through a machine similar to that used for tearing and cleaning rags intended to be made into paper. The water used in the operation is drawn off from time to time through a wire grating.

The material, thus chopped up and cleaned, is passed through rollers, where it is sufficiently ground. It is then put through other rollers,

where it is kneaded and worked up with the necessary composition.

The indiarubber, so mixed, is passed in the form of an endless web through four rollers placed vertically one above the other, and comes out a broad web fit for use.

The "gumming process" is performed by three rollers, Nos. 1, 2, 3. Nos. 1 and 2, the two lower ones, revolving side by side, and No. 3 revolving above and in contact with No. 2. The indiarubber is fed between Nos. 1 and 2, and the cloth to be gummed or covered is passed between Nos. 2 and 3, taking up from No. 2 a thin and equally spread coating of rubber.

The indiarubber cloth is cut out from the sheet by workmen, in the shape required to form shoes. The parts so shaped are put together by women, who form them on lasts, closing the joints by cohesion after touching them with camphine. Each woman finishes an entire shoe, and about 1,400 pairs are made daily.

The shoes are then covered with a coat of varnish, and taken to the stove drying room, where they are subjected to a heat from 250° to 280°, and allowed to remain a night.

To provide for an equal distribution of heat in the drying room two large heating stoves are placed underneath, each in a separate compartment. These are fed with fuel from the outside,

and the heat is admitted into the drawing room above, through several apertures pierced in the floor.

Thermometers are placed at the side of the room, and can be inspected through glass from the outside.

44. *Fishing-net Machines — Baltimore.* — These machines combine the general features of the powerloom and the lace machine.

They are made from 6 to 7 feet wide, according to the size of the mesh. One machine nets a $\frac{3}{4}$-inch mesh, and can be used for netting meshes of $1\frac{1}{2}$ and $2\frac{1}{4}$ inches. It works at the speed of twelve picks per minute, and a complete course of 100 knots is made in the width of this machine at each pick of the shuttle.

One woman with the machine can do the work of upwards of 100 hand net makers. The meshes are made rectangular, in the direction of the length of the net, and not diagonally, as in hand-made nets. The cost of the machine is $800 (about 160*l.*).

The manufacture of sailcloth is carried on in the mill where these machines are at work.

The throstles for spinning yarn for the sailcloth spin six hanks to the pound. The carding engine sliver is carried by the railroad system along a trough to the drawing frame. The main

cylinder of the carding engine is 36 inches in diameter, and the doffing cylinder 13 inches, the former making 135 revolutions, and the latter seven revolutions per minute. In the fly-frame the front roller makes 200 revolutions per minute, and the flyer from 1,900 to 2,000.

By some shipowners sailcloth made of cotton is preferred to that made from hemp.

Fishing nets made by hand are here also manufactured of cotton.

45. *Corn and Flour Mills — Pittsburgh.*— These mills employ forty persons, including clerks and all others engaged in the various departments, and are capable of producing 500 barrels of flour per day, each containing 196 lbs.

The grain is brought in bulk in boats alongside the building, and is raised by an elevator, consisting of an endless band, to which are fixed a series of metal cans revolving in a long wooden trough, which is lowered through the respective hatchways into the boat, and is connected at its upper end with the building where its belt is driven.

The lower end of the trough is open, and as the endless band revolves, six or eight men shovel the grain into the ascending cans, which raise it so rapidly that 4,000 bushels can be lifted and deposited in the mill in an hour.

The grain is next allowed to descend by a shoot or trough (the descent being regulated by traps) into a large hopper, resting on the platform of a weighing machine; its weight is then registered, and afterwards, by drawing a trap in the bottom of the hopper, the grain is allowed to descend by another shoot to a lower story.

It is next raised by an elevator to the highest story of the mill, where it is cleaned by passing through three different machines. The greatest care and attention is bestowed on this process, in order to insure the perfect cleansing of the grain preparatory to its being ground.

The grain is then conducted to the stock-hoppers, which feed eight pairs of grinding-stones.

A short length of the feeding-pipe of each pair is made of glass, through which the grain, as it descends, can be seen. The stones are 4 feet in diameter, and make 232 revolutions per minute.

The meal, when ground, is conveyed by means of a spiral conveyor to the cooling chamber, where a rake, revolving horizontally, is substituted for the old "hopper-boys." The meal is raked from the circumference to the centre, where it falls through a hole, and is taken to the bolting machine; it is there sifted, and separated into different qualities of flour. It is then con-

veyed to hoppers, from which it descends by spouts into the barrels in which it is packed.

46. *Elevators.*—The business of unloading vessels is followed as a special trade.

On the wharves in Buffalo may be seen, in many places, large signs announcing that elevators are kept for hire.

They are used for raising grain from vessels, storing it in warehouses, and transferring cargoes of wheat from one vessel to another, the grain in the last case being raised by the cans of the elevator, and then allowed to descend by a trough or shoot which guides it in any required direction.

CHAPTER VIII.

MANUFACTURING COMPANIES—CIVIL ENGINEERING—COTTON MILLS—CARPET MANUFACTORY—WOOLLEN AND FELT CLOTH MAKING—SEWING MACHINERY—COTTON GIN.

LOWELL, LAWRENCE, HOLYOKE, NEWHAVEN, WATERBURY.

47. *Textile Fabrics.*—The manufacture of textile fabrics is extending, particularly in the New England States.

Many new towns, founded for the purpose of carrying on this branch of manufacture, have in a short time attained considerable importance.

48. Lowell, Lawrence, and Holyoke, in Massachusetts, may be cited as instances well worthy of notice.

Lowell is situated on the banks of the Merrimack, about 25 miles north of Boston. It contains twelve large manufacturing establishments, belonging to different companies; of these, eight manufacture cotton goods, possessing in the aggregate about 350,000 spindles and 10,000 looms, and employing about 7,000 women and 2,000 men.

Two of them manufacture woollen goods, carpets, rugs, and broadcloths (one also combines the manufacture of cotton goods to some extent), possessing about 20,000 spindles and 600 looms, and employing about 1,500 women and 1,000 men.

One is a bleaching concern, employing 250 men.

One a machine shop, employing 700 men.

49. The capital stock of the companies varies in amount from $300,000 (60,000*l.*), to $2,500,000 (500,000*l.*); the total for the whole being $14,000,000 (2,800,000*l.*).

The interiors of the mills are kept in a state of great cleanliness. The rooms are lofty and properly ventilated: their white ceilings and walls combined with the blue hangers and columns, have a pleasing appearance.

The courtyards of many of the mills are laid out with flower-beds, interspersed with shrubberies, or shaded by lofty trees, and great care seems to be taken to keep them in good order.

50. Water power is used for driving the machinery in all the mills. It is obtained by means of a large and deep canal which is cut from the river at some distance above the town.

At the head of the canal where it joins the river, are floodgates, worked by large screws, all of which are driven by a small turbine. The masonry of the canal is constructed of blocks of granite, some of which are of very large dimensions.

The water thus conducted by canal is employed by the various companies in driving powerful turbine water-wheels. The mill gearing, conveying the power from the turbine to the different parts of the mill, is exceedingly well constructed.

The civil and mechanical engineering works employed in adapting water power to driving the machinery of the Lowell mills, have been most ably executed.

51. The first mills commenced operation in Lowell in 1823. Eight of the companies have been founded since 1830.

In 1828 the town contained 3,532 inhabitants: in 1850 its population was 33,385!

It has four banks and two institutions for savings, and a hospital established by the several companies for their sick operatives.

52. *Lawrence.*—Lawrence is situated about 26 miles north of Boston, on the Merrimack river, 9 miles below Lowell.

The first dwelling house was erected in September 1845, and in 1850 the town contained 8,500 inhabitants, and upwards of 1,000 dwellings. There were 15 schools, attended by 1,000 scholars, and conducted by 16 teachers.

The town now contains upwards of 13,000 inhabitants.

53. *Water Power.*—The water power was obtained by building a dam which has a 25 feet fall of water, 900 feet broad.

The dam is constructed in the form of a curve of solid masonry, imbedded in and bolted to the rock. It is 35 feet thick at the base, and averages 32 feet in height. Its cost was $250,000 (about 50,000*l.*).

The water is taken from the river above the dam by a canal just a mile in length, 100 feet broad at its upper end, and 60 feet broad at the lower, 12 feet deep in the middle, and 4 feet at the sides. Its total cost, including locks and other structures connected with it, was $200,000 (about 40,000*l.*).

54. *Cotton Mills.*—Seven large incorporated manufacturing companies have already commenced operations, and others are about to be established.

The largest cotton mills employ about 1,200 hands.

The machinery is driven by three turbine water-wheels, 8 feet in diameter.

55. *New Cotton Mill.* — Another establishment, lately erected, was being fitted with machinery for the purpose of manufacturing light cotton or cotton and woollen fabrics.

It is six stories high, each averaging 13 feet, 750 feet long, and 72 feet wide. There is also another building in the course of erection which will be 1,200 feet long, two stories high, with two wings, each 200 feet long, and three stories high, and is intended to be used for printing, dyeing &c. These mills are built of good bricks, measuring each 8 inches by 4 inches, and 2 inches thick.

The contract price for laying 100 bricks, including cost of material, is 1*l.* 16*s.* The entire erection was found to cost 50 cents (or 2*s.* 1*d.*), per square foot of flooring laid down.

The wool-combing machinery will be obtained from England. One woman working one of these machines will be able to comb 1,000 lbs. of wool per day, while a skilled hand wool-comber would only be able to comb from 8 to 10 lbs. in the same time.

The machinery of these mills will be driven by turbine water-wheels, of between 500 and 600 horse-power in the aggregate.

56. *Woollen Factory.*—The mills of this establishment are built in the form of a parallelogram, round three sides of which run buildings from three to five stories high. The front is formed by three detached mills, each 200 feet by 48 feet, and nine stories high, including attic and basement.

2,300 hands are employed in the manufacture of cassimeres, shawls, felt cloth, and other woollen goods.

57. *Felt Making.*—The whole waste from the mills mentioned in the preceding paragraph, is worked up in the manufacture of felted cloth.

The felt-making machines occupy but a small space.

A sliver of wool is taken from the carding engine and passed between two endless cloths; these carry it over a narrow steam-box, where it is steamed, and it is then passed under a vibrating pressing-plate, which operations cause the fibres to curl and interlace with each other, and so form a cloth.

The machinery of these mills is driven by seven breast wheels, each 26 feet in diameter.

58. *Machine Shop.*—There is a large machine shop, employing 500 hands in the manufacture of spinning and other machinery.

It is 400 feet long, 64 feet broad, and contains four stories of from 16 to 13 feet high. The forge shop is 230 feet long, 53 feet wide, and 17 feet high, and contains 32 forges. The foundry is 150 feet long, 90 feet wide, and 22 feet high.

59. *Holyoke—Cotton Mills.*—Holyoke is a manufacturing town situated on the banks of the Connecticut river.

A short notice of its history will serve to explain the way in which manufacturing companies are established in the United States.

In 1847, a company was formed for the purpose of turning to account the water power supplied by the river Connecticut, buying up the water privileges, and purchasing land to form the site of a manufacturing town.

The company subscribed a capital of $4,000,000, and was incorporated by the State of Massachusetts in 1847.

It succeeded in obtaining the water privileges, and upwards of 11,000 acres of land, besides other tracts in the vicinity. A dam, more than 1,000 feet long, was constructed across the river, in the summer of 1849.

The site of a town has been laid out with streets from 60 to 80 feet wide, calculated for a population of 200,000 inhabitants. It contains

already upwards of 5,000 inhabitants, and it is officially stated that the average sum appropriated for the education of each child was in 1852, $3 72c.

There is a 60 feet fall of water, which can be used by two sets of mills on different levels, affording power sufficient to drive the machinery of 100 large mills.

60. *Cotton Mills.*—Two cotton mills employing 1,100 hands, a machine shop employing 365 hands, and a paper mill, are already at work; others are in the course of erection.

One of the mills was spinning yarns Nos. 70 and 90, and making it into cloth of excellent quality.

Self-acting mules were used, and twelve piecers were minding 13,056 spindles; three hanks per spindle were spun in a day of 11½ hours.

One girl is able to weave of this yarn, on four looms, 100 yards of cloth per day. Upwards of seventy girls were brought from Scotland a short time ago.

The machinery is driven by turbine wheels.

In some mills, gearing is employed for driving the heavy shafting, but generally belts are much preferred; of these, some had a breadth of 20 inches, and were driven at the speed of nearly 1,800 yards per minute.

In some cases, in order to obtain sufficient adhesion, without having recourse to too tight a belt, the pulley is covered with leather, which is put on with white lead, and fastened with copper rivets.

61. *Hosiery.*—A large establishment at Waterbury is occupied exclusively in the manufacture of under-vests and drawers. The cloth waistbands of the latter are stitched by sewing machines, working at the rate of 430 stitches per minute. These machines have been worked with entire success for the last eighteen months.

The manufactured goods and the sewing machines are all that are shown to visitors. No stranger is ever permitted to see the hosiery looms; workmen, directors, and president, all enter into a bond not to disclose anything connected with the machinery of the company.

62. *Shirt Making by Machinery, Newhaven.*—In a shirt manufactory at Newhaven, entire shirts, excepting only the gussets, are sewn by sewing machines.

By the aid of these machines one woman can do as much work as from twelve to twenty hand sewers. The workwomen work by the piece, and are frequently able to finish their estimated day's work by 2 o'clock, and, when busy, work overtime.

63. *New Cotton Gin.*—This gin has, instead of saws, a card cylinder 8 or 9 inches in diameter, covered with coarse wire teeth, with considerably more bend or hook than the ordinary card tooth. The cylinder revolves against a spirally-fluted cast-iron roller, the tooth being about $\frac{1}{10}$ inch, and the space between the teeth $\frac{3}{10}$ inch broad.

To save the expense of turning and fluting the roller, it is cast in lengths of about 6 inches, which are bored and turned at the ends, and then put together, the tooth and space being left as they are cast.

In contact with the card cylinder, a cylindrical brush, 28 inches diameter, is made to revolve. The card cylinder makes 200 revolutions, the fluted stripper 400 in a contrary direction, and the cylindrical brush 800 revolutions per minute.

When the raw cotton is introduced with its seeds between the card cylinder and the stripper (which are placed just so far apart as to stop the seeds from passing), the hooked teeth of the card take hold of the fibres and pull them from the seed, which is held up against the roller as long as any fibres cling to it for the card teeth to hold by: the seeds are then released, and fall to the ground. The spirally-fluted roller causes

the position of the seed and cotton to be continually changing.

The cotton fibres, as they are taken round by the teeth of the card cylinder, are brushed off by the rapid revolution of the cylindrical brush, and carried to the bin.

The machine is about 60 inches wide, and can gin 1,500 lbs. of cotton per day. Its cost is $350 (70*l.*).

CHAPTER IX.

RAILWAYS—RAILWAY CARRIAGES—LARGE FOUR-MASTED SHIP—FIRE COMPANIES—FIRE ENGINES.

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64. *Railways.*—In the construction of railways, economy and speedy completion are the points which have been specially considered. It is the general opinion that it is better to extend the system of railways as far as possible at once, and be satisfied, in the first instance, with that quality of construction which present circumstances admit of, rather than to postpone the execution of work so immediately beneficial to

the country; to the future is left further progress and improvements.

A single line of rails nailed down to transverse logs, and a train at rare intervals, are deemed to be sufficient as a commencement, and as traffic increases, additional improvements can be made.

65. *Railway Crossings.*—Bridges are seldom thought necessary to carry the common highways across the railroads where they intersect, gates are even in many cases dispensed with, and a notice of "Look out for the locomotive when the bell rings," is considered a sufficient warning, and wayfarers are left to take care of themselves. Sharp curves and steep inclines are frequently submitted to for the sake of economy.

66. *Railroad Inclines.*—The railroad that connects the eastern and western parts of Pennsylvania, bringing the towns on Lake Erie and the great western rivers into direct communication with Philadelphia and the Atlantic, consists at present of a single line of rails carried over the lofty ridges of the Alleghany Mountains by a series of inclined planes.

These are five in number, and the summit of the highest is 2,600 feet above the level of the sea. The trains are dragged up each incline by

a rope attached to a drum worked by a stationary engine.

They are drawn across the plateaux which intervene between the inclines, in some cases by horses, in others by small locomotives. A new road is, however, being constructed which will cross the mountains by one long winding incline. The ascent will be so gradual in its circuitous course, that a locomotive will be able to ascend and descend with its train of carriages.

It is calculated that four hours will be saved by the substitution of this new route, and the dispensing with the stationary engines.

It is doubtful whether the delay would not have been very considerable, had the construction of the railroad been postponed until means had been found for executing these great works in the first instance.

67. *Street Railroads.*—It is a common practice to detach the carriages from the engine at the outskirts of towns, and draw them by horses along rails laid down in the streets.

Many objections may be made to this system, and it seems, on the whole, disadvantageous; a circuit of rails carried round the town would be more preferable.

68. *Railroad Cars.*—The construction of the

railroad cars or carriages commonly used in the United States has been frequently described.

They are very long, and are supported at each end on four-wheeled trucks, on which they swivel when turning the sharp curves, which are of ordinary occurrence.

A car constructed for sixty passengers measured 40 feet long, 8½ feet wide, and 6½ feet high, inside measure; small benches with reversible backs, having each two seats, are ranged parallel to each other down both sides of the carriage, leaving a passage clear from the door at one end to that of the other. The car afforded upwards of 2,200 cubic feet of space, or 37 feet per passenger. Its weight was 11 tons, giving a dead weight of about 3½ cwt. per passenger.

The cost of a 60-passenger car is about $2,000 (400*l.*).

A contrivance has been lately tried for excluding the dust by connecting the different carriages together by indiarubber curtains at the ends, the air being admitted through the roof of the first carriage.

The object sought to be obtained is, a current of air running through the entire train, and always setting outwards from the interior of the carriages. The results did not appear to answer fully the expectation which had been formed

69. *A Four-masted Clipper Ship.*—A large clipper ship of 4,000 tons was being built at Boston; the length of keel was 287 feet, length on deck 320 feet, extreme breadth of beam 52 feet, and depth of hold 30 feet. Her keel is of rock maple in two thicknesses, the frame is of seasoned white oak, dowelled, and bolted together through the dowelling with $1\frac{1}{4}$ inch iron. The frame inside is diagonally crossbraced with iron, the braces being 4 inches wide, and $\frac{3}{4}$ inch thick, bolted through every timber: these braces extend from the floor-heads to the top timbers, and form a perfect network of iron over all her frames fore and aft.

She has five depths of midship keelsons, each 16 inches square, three tier of sister keelsons, 15 inches square, bolted vertically and horizontally. There are four tiers of bilge keelsons on each side, 15 inches square. Ceiling, from bilge to lower deck 15 inches, scarped and bolted edgewise.

She has three full decks, securely fastened with fore and aft knees; the hanging knees are extra fastened, having in the lower hanging knees 18 bolts, $1\frac{1}{4}$ inch iron; middle deck, 20 bolts; also upper deck hanging knees, 20 bolts, and all of oak. Beams in lower deck, 14 by 16; in middle deck, 15 by 17; in upper deck, 12 by 16, and some 12 by 20 inches.

Lower deck main hatch is 14 by 20; middle deck, 14 by 16; and main deck 14 by 11.

She has a hurricane deck over all, merely for working the ship, thereby obviating the difficulty in obstructions from houses, spare spars, water casks, &c.

Her mainmast is 126 feet long, 98 above deck, diameter 44 inches; masts made of hard pine, to carry two stationary yards with trusses, the same as used on lower yards; fore and main deck alike, and those on the mizenmast the same as those on the other masts above the lower yards, so that, except the courses, all her sails will have duplicates on every yard fore and aft. Her main yard is 110 feet long, the others in proportion; she will have a fourth mast, principally to lead the mizen braces, to prevent the difficulty arising from mizen braces leading forward, and hauling the mast out of place.

The model of the ship was said to promise a combination of swiftness, buoyancy, and beauty that has never been excelled. Notwithstanding her vast size, such is her length and buoyancy that, when loaded ready for sea, her draught of water will not exceed 23 feet, a common draught for ships half her size.

70. *Fire Companies.*—The fire companies are formed in many towns of volunteers, who do

not receive pay, but enjoy certain immunities from taxes and militia service.

The parade day of the fire companies of a town is considered as a fête, the companies of other towns are invited to attend, and test the qualities of their respective engines in a trial as to which can throw the highest stream of water. At a meeting of firemen, held in Newhaven, thirty-six companies attended, each dressed in a distinctive uniform, and averaging about fifty strong.

A prize was given to the company whose engine succeeded in throwing the highest stream of water.

The engines played against a pole 150 feet high, through hose 450 feet long. Two engines, one having a 10-inch, the other an 8-inch cylinder, threw a stream 143 feet high, and carried off each a prize. These engines, however, were surpassed the following day by another engine with a 10-inch cylinder, which threw a stream over the pole.

CHAPTER X.

GOVERNMENT WORKS.

NEW YORK, BOSTON, WASHINGTON, SPRINGFIELD.

71. *Navy Yard, New York.*—This navy yard is situated on Long Island, opposite the city. It covers a considerable extent of ground, and has many large storehouses and workshops, and gives employment to between 400 and 500 men.

It contains the most capacious dry dock in the United States, constructed to admit vessels of the largest size.

They may be completely docked, and the water pumped out in four hours and a quarter. The quantity of water to be removed is about 610,000 cubic feet. It is pumped out by a condensing engine, with a 50-inch cylinder, 12 feet stroke, and 32 feet beam.

The cut-off motion is self-adjusting, so that more steam is admitted into the cylinder as the height to which it has to pump the water increases.

The framing of the engine is in the form of Gothic columns, supporting arches, all painted and bronzed. All the work not painted is highly polished.

The whole is surrounded by a bronzed rail, and a cast-iron flooring, ornamented with stars in relief, covers the floor.

The engine house is about 60 feet square, and 50 feet high. The boilers are placed in a fire-proof room adjoining; they are three in number, 26 feet long, 7 feet in diameter, and are ordinarily used at a pressure of 50 lbs.

The engine works two draining pumps, each 63 inches in diameter, having 8 feet stroke, one being connected to each arm of the beam.

The whole cost of the dock and its appendages is estimated at $2,000,000 (about 400,000*l.*).

72. *Navy Yard, Washington.*—In this yard there are from 500 to 600 men in the various departments, employed in the manufacture of ordnance, marine engines, chain cables, anchors, &c.

Experiments were being made with a large gun, carrying 240 lb. shot, and also with a pendulum mortar.

The quality of the metal of which each gun is composed is tested and registered, and a sample piece preserved.

73. *Boston Navy Yard.*—The Boston Navy Yard is of great extent, and contains three large sheds for ship-building, one of which is now used as a store for timber; another is occupied by the ship "Virginia," which has been on the stocks for more than twenty years; the third is empty. The manufacture of rope is carried on on a very extensive scale. A building 1,360 feet long, contains a rope walk where a length of upwards of 1,200 feet of rope may be made. There are also the means of making 24-inch cables.

Machinery is used for making sheaves for ship blocks. An ingenious machine is employed for boring the sheaf, and recessing it on both sides for receiving the bush. Two lathe headstocks are mounted on a frame, and carry the small revolving cutters for making the recesses. An universal concentric chuck, with three "jaws," having a large hole in its centre, is mounted between the headstocks. This carries the work, and has a vertical adjustment.

74. *Springfield Armoury.* — Springfield Armoury is beautifully situated on an eminence overlooking the town. The various buildings together form a quadrangle; the grounds, which are tastefully laid out, occupy an extent of about 40 acres.

I was conducted over the establishment by

the Commanding Officer, Colonel Ripley, and the master machinist, Mr. Buckland, who is the inventor of the principal machines employed in the manufacture of firearms.

The front building, which has a handsome centre tower, is used as an arsenal for muskets. It contains 100,000 muskets, stacked with beautiful uniformity.

The barrels are made in mills, situated on the banks of a small river at some distance. The lighter parts of the musket, as the stock, the lock, guards, &c., are manufactured in the workshops attached to the Armoury.

The machines employed in the manufacture of the musket stocks are worthy of particular notice. By the kind courtesy of Colonel Ripley, facilities were afforded me for observing the time occupied in each operation.

The stocks are purchased rough from the saw for twenty-eight cents (or 1*s.* 2*d.*) each.

	Time occupied.	
	Min.	Sec.
1. They are roughly turned in Blanchard's machine, which has been in operation nearly thirty years	4	11
2. While one stock is being turned, the attendant is able to face and slab another by a circular saw..	3	30
3. The stock is next taken to what is called a "spotting" machine, where the sides are cut flat in different parts, to serve as bearings, or points to work from in future processes; this is done by two pairs of horizontal cutters, one pair at each end, and three single cutters in the centre	0	7

	Time occupied. Min. Sec.
4. Next to a "barrel-bedding" machine, where a groove is cut for the barrel; this is done by four bits set with their guides in a row, in a sliding frame combined with a horizontal cutter, with a vibratory motion given by hand for shaping the groove conically, and a vertical bit for recessing	1 $7\frac{1}{2}$
The next operation, that of finishing the groove by chisel, is performed by hand in 1 min. 42 sec.	
5. The stock is then sawn to the required length ..	0 $11\frac{1}{2}$
6. A "bed" is next recessed for the side plate, the sides of the stock are flattened by two vertical cutters, and the bed is recessed by a horizontal bit	1 $11\frac{3}{4}$
7. The edges of the stock are then faced by a horizontal cutter	0 14
8. The stock is next taken to a butt-plate machine, where a bed is recessed and screw holes made for the butt plate by a horizontal bit and screw, and also a vertical bit and screw	0 $21\frac{1}{2}$
9. Next to a "band-fitting" machine, where three horizontal cutters cut three straight bands, and a fourth bevils the upper or bayonet band ..	0 $22\frac{3}{4}$
10. Next to a "band-finishing" machine, where four horizontal cutters round off the parts intervening between the bands	0 $28\frac{1}{2}$
11. The stock is then turned a second time, in order to smooth its surface, 1st from the butt to the breech tang	8 35
12. 2nd, from the breech tang to the end of the stock	5 28
13. It is next taken to the "lock bedding" machine, where the bed for the lock is recessed and shaped by five vertical bits set with their guides in a circular frame, at equal distances from each other. The driving-strap is made to run on a loose pulley fixed above the circular frame, and as each bit is brought into operation, the band drops from the loose pulley on the driving pulley of the bit which is brought underneath it, and is raised, when the operation is finished, to its former position, ready to descend on the pulley of the next bit. The cuttings are blown away by two fan-pipes	0 $46\frac{3}{4}$

	Time occupied.
	Min. Sec.
14. Next to the "guard-bedding" machine. It was similar in its construction to the former, but it carried four bits instead of five, and recessed and shaped the bed for the guard	0 51
15. The holes for the side screws were then bored ..	0 15
then for the tang screw	0 $8\frac{3}{4}$
16. The stock was lastly taken to the "band, spring, and ramrod-fitting" machine. A vertical revolving cutter grooved recesses for the band-springs, a horizontal cutter recessed the groove for the barrel	0 $55\frac{1}{4}$
A hand operation then finished off the whole. Time, 35 seconds .. .. .. 35 sec.	
Total time of machine operations	28 $45\frac{1}{4}$
Ditto hand ditto	2 17
	31 $2\frac{1}{4}$
Allowance for double simultaneous operations during turning	8 58
Man's time given to the whole operations of making a complete musket-stock	22 $4\frac{1}{4}$

The complete musket is put together in three minutes. All parts are so exactly alike that any single part will, in its place, fit any musket.

The general principle adopted in the construction of these machines is that of guiding the cutter in its course, by a shaper or "former," that is, a pattern made exactly of the form in which it is required that the work should be shaped.

The number of muskets made in the year 1852 amounted to 19,800.

75. *Coast Survey Office, Washington.*—Workshops are attached to the Coast Survey Office, where copies of the standard weights and measures of the United States are made. The office supplies the capital of every State in the union, in addition to the standard weights and measures, with three very accurate balances.

No. 1 is constructed to weigh from 50 lbs. down to 10 lbs.

No 2 to weigh from 10 lbs. to 1 lb.

No. 3 to weigh from 1 lb. to $\frac{1}{10000}$ oz.

The estimated cost of the three is $4,600 about 900*l.* The latter balance was tested, and deflected by the $\frac{1}{10000}$ oz. In weighing 1 lb. the effect of the addition of $\frac{1}{200}$ grain was instantly visible.

When the balance is not in use, the beam is made to descend by means of a screw, so that two external cones, placed on its under side, rest in two internal cones fixed on the supporting frame. Two steel discs attached to the chains of the scales are, by the same screw, made to descend, and rest upon the frame. Thus the whole balance is supported, and there is no continued strain on the knife edges.

A lever worked by hand acts upon the two

short vertical rods placed under the scales, and adjusts them evenly, before commencing the operation of weighing.

The balance stands on four feet, each adjustable by screws.

The full set of standard weights and measures supplied by the office consists of—

1. A set of standard weights from 1 lb. to 50 lbs. avoirdupois; and 1 lb. troy.

2. From 1 oz. down to $\frac{1}{10000}$ oz. troy.

3. A yard measure.

4. Liquid measures. The gallon and its parts down to half-pint inclusive.

5. A half-bushel measure.

Twenty-one States have been supplied, and other sets are being prepared for the remaining States. There are thirteen workmen employed.

The United States standard yard has been obtained from a 7-feet standard procured from England.

It is made of gun-metal, about 2 inches broad and $\frac{3}{8}$ inch thick, and has a thin strip of silver, $\frac{1}{5}$ inch broad, let into it through its entire length. It is divided into small divisions, each being an aliquot part of an inch. The standard was obtained by taking the mean of a great number of measurements made from different points in the 7 feet scale.

A set of standards has been presented to

France, and a set of French standards was presented to the United States in return.

It is a matter of surprise that while the people of the United States have long felt and appreciated the benefits of their decimal monetary system, the old English system of weights and measures has not yet been abolished by the Legislature. Its inconveniences are much complained of, and custom has tried to remedy its evident defects to a great extent by adopting the plan of reckoning by 100 lbs. (instead of the cwt. or 112 lbs.) and by 1000 lbs.

Monetary accounts are kept, and calculations are made with the greatest facility in dollars and cents, the dollar (4*s*. 2*d*.) being divided into 100 cents (a cent $\frac{1}{2}d$.). Convenient coins called "dimes" are in circulation, 10 cents being equal to one dime, and 10 dimes making a dollar. Quarter dollar and half dollar pieces are also commonly used; there appears to be no reason why a decimal system would not afford equal advantages, if applied, as it doubtless will be eventually, to the scales of weights and measures.

The Coast Survey Office has custody of two instruments used in measuring by means of end measurements. A base line 7 miles long, was measured on an island near Charleston in about

six weeks. The measuring instruments were supported on two adjustable stands.

They were made on the compensating principle, and inclosed in a double case of tin, to prevent, as much as possible, their being affected by changes of temperature. The ends of the instruments were of agate, one flat, the other having a knife edge. The latter was made to slide, and was connected by a bell-crank lever to a spirit level, which indicated when the end measures were in contact, according to the method employed by Bessel, in making standard measures in Prussia.

CONCLUSIONS.

THE parts of the United States which I visited form, geographically, a small portion of their extended territory, but they are the principal seats of manufactures, and afford ample opportunities for arriving at general conclusions.

I could not fail to be impressed, from all that I saw there, with the extraordinary energy of the people, and their peculiar aptitude in availing themselves to the utmost of the immense natural resources of the country.

The details which I have collected in this report show, by numerous examples, that they leave no means untried to effect what they think it is possible to accomplish, and they have been signally successful in combining large practical results with great economy in the methods by which these results are secured.

The labouring classes are comparatively few in number, but this is counterbalanced by, and indeed may be regarded as one of the chief causes of, the eagerness with which they call in the aid of machinery in almost every department of industry. Wherever it can be introduced as

a substitute for manual labour, it is universally and willingly resorted to; of this the facts stated in my report contain many conclusive proofs, but I may here specially refer, as examples, to plough making, where eight men are able to finish thirty per day; to door making, where twenty men make 100 panelled doors per day; to last making, the process of which is completed in 1½ minutes; to sewing by machinery, where one woman does the work of twenty; to net making, where one woman does the work of 100. It is this condition of the labour market, and this eager resort to machinery wherever it can be applied, to which, under the guidance of superior education and intelligence, the remarkable prosperity of the United States is mainly due. That prosperity is frequently attributed to the possession of a soil of great natural fertility, and it is doubtless true that in certain districts the alluvial deposits are rich, and the land fruitful to an extraordinary degree; but while traversing many hundred miles of country in the Northern States, I was impressed with the conviction that the general character of the soil there was the reverse of fertile.

It is not for a moment denied that the natural resources of the United States are immense, that the products of the soil seem capable of being multiplied and varied to almost any extent,

and that the supplies of minerals appear to be nearly unlimited.

The material welfare of the country, however, is largely dependent upon the means adopted for turning its resources to the best account, at the same time that the calls made upon human labour are reduced as far as practicable.

The attention paid to the working of wood, some details connected with which I have included in the report, is a striking illustration of this. The early settlers found in the forests which they had to clear, an unlimited supply of material, which necessity compelled them to employ in every possible way, in the construction of their houses, their furniture, and domestic utensils, in their implements of labour, and in their log-paved roads.

Wood thus became with them a universal material, and work-people being scarce, machinery was introduced as far as possible to supply the want of hands. The character thus given to one branch of manufactures has gradually extended to others. Applied to stone-dressing, for example, one man is enabled, as I have shown, to perform as much work as twenty masons by hand. So great again are the improvements effected in spinning machinery, that one man can attend to a mule containing 1,088 spindles, each spinning three hanks, or 3,264

hanks in the aggregate per day. In Hindoostan, where they still spin by hand, it would be extravagant to expect a spinner to accomplish one hank per day; so that we find the same amount of man's labour, by the aid of improved machinery, doing more than 3,000 times the work. But a still more striking comparison between hand and machine labour may be made in the case of lace making in England. Lace of an ordinary figured pattern used to be made "on the cushion" by hand, at the rate of about three meshes per minute. At Nottingham, a machine attended by one person will now produce lace of a similar kind at the rate of about 24,000 meshes per minute; so that one person can, by the employment of a machine, produce 8,000 times as much work as one lace maker by hand.

The results which have been obtained in the United States, by the application of machinery wherever it has been practicable to manufactures, are rendered still more remarkable by the fact, that combinations to resist its introduction there are unheard of. The workmen hail with satisfaction all mechanical improvements, the importance and value of which, as releasing them from the drudgery of unskilled labour, they are enabled by education to understand and appreciate. With the comparatively superabundant

supply of hands in this country, and therefore a proportional difficulty in obtaining remunerative employment, the working classes have less sympathy with the progress of invention. Their condition is a less favourable one than that of their American brethren for forming a just and unprejudiced estimate of the influence which the introduction of machinery is calculated to exercise on their state and prospects. I cannot resist the conclusion, however, that the different views taken by our operatives and those of the United States upon this subject are determined by other and powerful causes, besides those dependent on the supply of labour in the two countries. The principles which ought to regulate the relations between the employer and the employed seem to be thoroughly understood and appreciated in the United States, and while the law of limited liability affords the most ample facilities for the investment of capital in business, the intelligent and educated artizan is left equally free to earn all that he can, by making the best use of his hands, without let or hindrance by his fellows.

It may be that the working classes exhibit an unusual independence of manner, but the same feeling insures the due performance of what they consider to be their duty with less

supervision than is required where dependence is to be placed upon uneducated hands.

It rarely happens that a workman who possesses peculiar skill in his craft is disqualified to take the responsible position of superintendent, by the want of education and general knowledge, as is frequently the case in this country. In every State in the Union, and particularly in the north, education is, by means of the common schools, placed within the reach of each individual, and all classes avail themselves of the opportunities afforded. The desire of knowledge so early implanted is greatly increased, while the facilities for diffusing it are amply provided through the instrumentality of an almost universal press. No taxation of any kind has been suffered to interfere with the free development of this powerful agent for promoting the intelligence of the people, and the consequence is, that where the humblest labourer can indulge in the luxury of his daily paper, everybody reads, and thought and intelligence penetrate through the lowest grades of society. The benefits which thus result from a liberal system of education and a cheap press to the working classes of the United States can hardly be over-estimated in a national point of view; but it is to the co-operation of both that they must undoubtedly

be ascribed. For if, selecting a proof from among the European States, the condition of Prussia be considered, it will be found that the people of that country, as a body, have not made that progress which, from the great attention paid to the education of all classes, might have been anticipated; and this must certainly be ascribed to the restrictions laid upon the press, which have so materially impeded the general advancement of the people. Wherever education and an unrestricted press are allowed full scope to exercise their united influence, progress and improvement are the certain results, and among the many benefits which arise from their joint co-operation may be ranked most prominently the value which they teach men to place upon intelligent contrivance; the readiness with which they cause new improvements to be received and the impulse which they thus unavoidably give to that inventive spirit which is gradually emancipating man from the rude forms of labour, and making what were regarded as the luxuries of one age to be looked upon in the next as the ordinary and necessary conditions of existence.

(Signed) JOSEPH WHITWORTH.

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